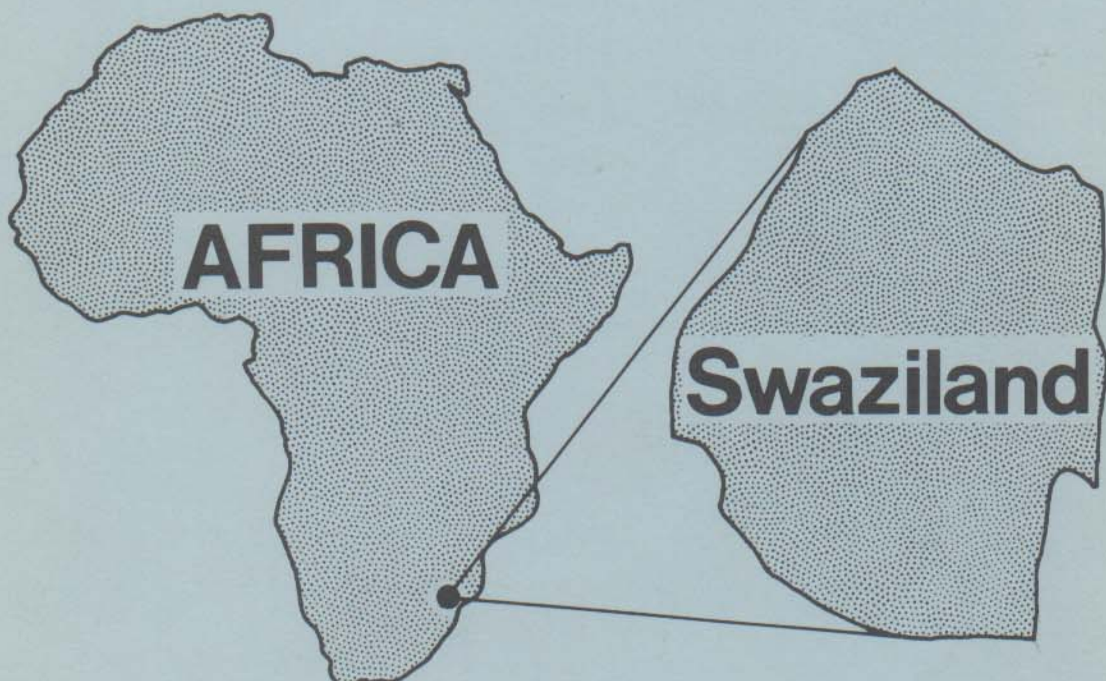
SWAZILAND

WATER AND RELATED LAND RESOURCES FRAMEWORK PLAN

APRIL 1981



PREPARED BY
OMAHA DISTRICT CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

Report Documentation Page

Report Date 01APR1981	Report Type N/A	Dates Covered (from... to) -

Title and Subtitle Swaziland: Water and Related Land Resources Framework Plan	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) U.S. Army Corps of Engineers Omaha District Omaha, NE	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es)	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes The original document contains color images.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 437	

PREFACE

This report was prepared for the Government of Swaziland by the U.S. Army Corps of Engineers with funds provided by the United States Agency for International Development. It consists of five parts: Part I, Executive Summary; Part II, Supply-Demand Analysis; Part III, Detailed Planning; Part IV, Base Studies; and Part V, Plates.

The studies presented in this report were completed over a period of 9 months. The main study team consisted of eight individuals of various professional disciplines from the Omaha District. This team spent 5 weeks in Swaziland in June and July of 1980 collecting data and preparing a draft report on water supply and demand. Upon returning to the United States, the team, with the support of other Omaha District personnel, spent 6 weeks completing the studies and approximately 2 weeks producing a draft report.

The draft report was forwarded to the Government of Swaziland for its review and comment. Two members of the study team spent 1 week in Swaziland in October of 1980 reviewing the draft report with representatives of the Government of Swaziland. The two study team members also met with representatives of the World Bank to discuss the draft report. At that time, it was learned that the Republic of South Africa (RSA) had completed and published a development plan for those rivers of common interest between Swaziland and the RSA. The Government of Swaziland requested that the Omaha District review the RSA development plan and analyze the effects of its implementation on water resources development in Swaziland. Because of the review and analysis of the RSA development plan, some portions of the framework plan presented in our draft report have been considerably altered. Most of these alterations are in the Preliminary Plan Formulation portion of the Executive Summary and in the Supply-Demand Analysis.

The final product is not a detailed plan. Rather, it relies on the most significant variables and data to point out major problems and the direction required to resolve them. In this respect, it does respond to the immediate needs of the Government of Swaziland; i.e., to understand the major short- and long-term water-related problems and opportunities and to set the course for the future development of the water resources of Swaziland.

PART I - EXECUTIVE SUMMARY

PART II - SUPPLY-DEMAND ANALYSIS

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PART I

EXECUTIVE SUMMARY

PART I

EXECUTIVE SUMMARY

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INTRODUCTION

Late in 1979, the Government of Swaziland (GOS) requested assistance from the United States Agency for International Development (USAID) in the preparation of a water resources development plan. Under the authority of the Foreign Assistance Act of 1961, as amended, the U.S. Army Corps of Engineers agreed to prepare a Terms of Reference (TOR) for the requested assistance. The task was assigned to the Ohio River Division and was completed in October 1979. In early 1980, the GOS requested that the TOR be implemented. The U.S. Army Corps of Engineers agreed to undertake the investigation and prepare the water resources development plan defined in the TOR; the task was assigned to the Omaha District. The time and funds required to complete the work as described in the TOR were not available. A revised TOR reflecting the reduced scope of effort was developed. The Participating Agency Service Agreement and the revised TOR are included in Part IV, Base Studies.

The purpose of this development plan is to provide a conceptual framework for future water resources development decisions in Swaziland in order to enable the GOS to be effective in its negotiations with neighboring countries regarding international rivers.

This development plan is referred to synonymously as a conceptual plan, an outline plan, and a framework plan. Each term is used to define the scope and is intended to reflect that the plan is broad geographically--it covers the entire country and parts of other countries--and is very limited in the depth and detail of the evaluations of specific projects. In this respect, it was important to quickly sort out the key variables and conditions from those that are likely to be insignificant in major water resources development decisions. Emphasis was placed on those key variables and conditions.

Because of the short time allowed for completion of the study, existing data and previous studies were used. The major data sources were the updated stream and rainfall records. The major previous studies used were the "General Plan for Development and Utilization of Water Resources," 1970; the "Ngwavuma River Basin Study," 1977; "Soil and Land Capability in Swaziland," 1970; and "Possible Future Development in the Republic of South Africa of the Rivers of Common Interest with the Kingdom of Swaziland," 1980. A complete list of references is included in Part IV, Base Studies.

FINDINGS AND CONCLUSIONS

This study was conducted over a very brief period of time. This study did not include a detailed analysis of all the water and related land resources problems in Swaziland; however, the very intensive study effort allowed observations and evaluations that resulted in the identification of some important factors that should be considered in future water resources decisions.

GENERAL FINDINGS

Irrigated agriculture is the key consideration in future water resources development. It is by far the largest consumer of water and is the key to the economic and financial feasibility of water resources development.

The GOS is hoping that irrigated agriculture and related industrial opportunities can assist in alleviating foreseeable problems in employment, government revenue, value added, foreign exchange earnings,

importation, and environmental degradation. This study indicates that the development of large-scale irrigation has the potential to make significant contributions to goals and objectives in these problem areas. Significant development of this irrigation potential would require a unified and complete commitment of the many and diverse interests involved.

Evaluations of current and proposed developments in the Republic of South Africa (RSA) indicate that irrigation could significantly increase abstractions from current reservoirs and these abstractions could be further increased with the addition of new reservoirs. Depending upon the basin, these RSA actions could create significant impacts on current and potential water resources development in Swaziland.

Hydropower does not add significantly to the economic viability of water resources development because of the inexpensive supply available from the RSA and the insignificant market for peaking power. The development of the country's irrigation potential would not preclude the later addition of hydropower should conditions change.

Other multiple-purpose uses of water resources development such as recreation, tourism, fish and wildlife, and domestic supply, do not have the potential for adding significant economic value. None of these uses is likely to strongly affect the water available for irrigation; however, the opportunity exists for significant social and environmental gains and should not be overlooked in more detailed planning of multiple-purpose projects. This is particularly true if a better distributed supply of high quality water for domestic use can be provided.

POTENTIAL PROJECTS

With effective management and optimistic market values for agricultural produce, a number of economically feasible irrigation projects could be developed.

The Lomati river could provide water for 3,600 hectares (ha) of additional irrigated land without storage reservoirs. Construction of a reservoir would allow for the development and irrigation of an additional 14,200 ha.

If the RSA increases abstractions from its existing reservoirs on the Komati river to their full potential, Swaziland would experience severe shortages. With the additional reservoirs proposed for construction by the RSA, these shortages could become even more severe without the specified releases which the RSA proposes to reserve for Swaziland. Under any condition, storage would be required in Swaziland to make up for the current and potential shortages.

In the Mbuluzi basin, it appears that the land irrigated by water from the new Mnjoli reservoir could be increased by up to 5,000 ha if the Swaziland Irrigation Scheme (SIS) return flows are maintained. No additional storage could significantly increase the irrigation potential; however, conservation practices, if implemented with the planned Ngomane Irrigation Scheme, could increase additional irrigation potential beyond the 5,000 ha presented in this report.

Current irrigation development in the Ngwavuma basin experiences frequent shortages. Construction of a storage reservoir would provide for these shortages and would provide water to irrigate an additional 2,400 ha. A large area of the most suitable land for irrigation in Swaziland is located in the Ngwavuma basin. Irrigation of this land would require transporting water from the Usutu river.

There is currently a surplus of water in the Usutu basin. Increased abstractions from existing RSA reservoirs and additional abstractions from proposed RSA reservoirs could reduce this surplus by about 50 percent. The remaining surplus, if combined with the yield from two dams (DS 0.1 and DS 0.2) currently under detailed study by the GOS and the proposed RSA reserve from the Upper Great Usutu, would provide about 90 percent of the water required for the irrigation of more than 18,000 ha in the Mapobeni, Big Bend North, and Big Bend South areas of the Lower Great Usutu. A storage reservoir on the Upper Great Usutu could provide enough water to complete irrigation in the Mapobeni area and to irrigate an additional 6,600 ha in the Lower Great Usutu basin. A storage reservoir in the Ngwempisi together with a reservoir in the Mkondo could provide enough additional water to irrigate 10,900 ha. This water could be diverted to the Ngwavuma to irrigate the very good quality land in that basin.

STUDY NEEDS

As requested by the GOS, estimates of the physical and economic potential for irrigation development are optimistic. Detailed planning is required to arrive at firm conclusions regarding this potential. The study needs, costs, and schedules are presented in detail in Part III. These needs are briefly outlined in the following paragraphs.

The flow records in most cases do not cover a long enough period to determine reliable stream yield potential. A more sophisticated analysis is required; a method of analyzing runoff that is not so highly dependent upon recorded values could be used.

Reservoirs were evaluated using very limited site data. Detailed surveys, site investigations, sediment analyses, and spillway design studies are required to determine the best sites and reliable cost estimates.

General soils maps were used to identify lands suitable for irrigation and lands requiring drainage. Because of the large variation of soils, detailed soils surveys in all areas identified as potentially suitable for irrigation are required.

Reliable information regarding RSA development and operation plans is required (especially in the Komati basin) for detailed planning.

Crop variety and yield potential should be evaluated in greater detail. Existing crop research data should be examined in detail. Additional crop research should be conducted, particularly in connection with the Vuvulane irrigation scheme.

Mathematical models capable of handling multiple reservoir sites, a number of demand locations, and alternative reservoir release and downstream flow guarantee conditions should be developed to evaluate complex systems, such as the Usutu and the Komati basins, and to evaluate the effects of the RSA border flow proposals.

Multiple-purpose opportunities must be explored in much greater detail. The social and environmental benefits as well as the economic benefits should be identified.

Detailed market studies are required to determine if additional supplies of agricultural products would significantly affect prices. If product prices are likely to be affected by additional supplies, a way to market the additional products without a price reduction should be developed.

A realization of the estimated economic benefits of irrigation would require aggressive management to rapidly develop the full agricultural potential of the irrigated land. The resulting social and cultural effects could create either a strong adverse reaction or, if

properly planned and implemented, the attainment of long-term social, cultural, environmental, and economic goals with a minimum short-term disruption. A great deal of careful research and planning is required in this area.

This study verifies the GOS's opinion that the development of irrigated agriculture is required to meet the goals of the country. Improvement in the collection and evaluation of water resources data is required to assure wise development decisions and effective management of water resources development. The data collection network is constantly being improved. The human resources required to maintain the system and attend to the data in a manner consistent with the importance of water resources in the country's future need improving as well. The provision of an adequate, trained staff and the cooperation of all ministries are prerequisites to successful attainment of the country's goals for water-related land resources development.

DESCRIPTION OF THE AREA

PHYSIOGRAPHY

Swaziland is a small, landlocked country located in south-southeastern Africa. It is bordered by the RSA except for a small area on the east which adjoins Mozambique. The country has a maximum north-south length of 193 kilometers (km) and a maximum east-west width of 145 km and is shown on plate 1. Swaziland covers approximately 17,400 square kilometers (sq km) and is divided among the following four regions: Highveld, Middleveld, Lowveld, and Lebombo.

As shown on plate 2, these roughly parallel regions extend from north to south; the divisions of the regions are regarded as approximate midpoints of zones of separation and not as exact boundaries.

The Highveld region covers an area of approximately 5,200 sq km. The elevation of this region ranges between 1066 and 1372 meters above mean sea level (m.s.l.). There are many steep (50-percent) slopes and average gradients exceed 18 percent.

The transition from the Highveld region to the Middleveld region is notable. Rocky hills occur less frequently and the earth becomes more undulating with wider valleys and open plateaus.

The Middleveld region has an average elevation of from 610 to 762 meters m.s.l. and covers approximately 4,900 sq km. This region contains hilly country and well-watered valleys consisting of mountains on the west side to gently undulating grassland on the east side. The median slope is 12 percent.

The Lowveld region is known as "Lihlanze" which means a warm place with trees. This region covers approximately 5,700 sq km and is a direct contrast to the other regions. The elevation ranges from 182 to 364 meters m.s.l. The median slope is 3 percent--the most gentle relief of all the regions.

The Lebombo region covers approximately 1,600 sq km and includes the Lebombo mountains. These mountains consist of a plateau of bare igneous rocks. This region rises abruptly in elevation from the Lowveld region to 610 meters m.s.l. In this region, the highest points in elevation are at Siteki at 762 meters m.s.l. and at Mananga Beacon at 823 meters m.s.l.

CLIMATE

The climate of Swaziland varies from the subtropical, near humid Lebombo region in the east to the humid, near temperate Highveld region. The two distinct seasons in Swaziland are summer, which occurs from October to March, and winter, which occurs from April to September.

Winter is a typically dry period. During summer, 75 to 83 percent of the annual rainfall occurs. The Lowveld region receives the least amount of moisture with some areas receiving a mean annual rainfall of just over 508 millimeters (mm); this region faces the greatest threat of drought. The Highveld region receives the most precipitation with some areas receiving a mean annual rainfall of near 1,500 mm. The rains are seriously deficient in 1 out of every 10 years, even in the Highveld region. The long-term mean annual rainfall for the whole country is 914 mm.

GEOLOGY

The geologic formations in Swaziland consist of rocks of the Precambrian era and the Karroo period. The Transvaal plateau is a broad, undulating, featureless country underlain by flat or gently dipping sedimentary formations of the Karroo period. Strongly folded and faulted metasediments of the Swaziland system form the mountains along the northwestern boundary of Swaziland. Farther south, a broad outcrop of Insuzi lavas and rock of the Usushwana basic complex follow the border in a southeasterly direction. The Mahamba mountains in the southern part of the country were formed from similar lavas and associated sediments. The eastern limit of the Transvaal plateau coincides with the boundary of the sedimentary rocks.

The Highveld region is predominantly granite, though Precambrian era sediments, volcanics, and basic igneous rocks form extensive outcrops.

Granite and granitic gneisses are predominant in the Middleveld region. The warmer, humid environment has caused greater weathering of these rocks resulting in friable soils with good drainage characteristics.

The Lowveld region presents a complete change of geologic conditions. Most of the region consists of sedimentary and volcanic rocks of the Karroo period. The coal-bearing Karroo sediments consist of shales and sandstones adjacent to the Middleveld granites, which are overlain by a thick series of basalts to the east. Extensive sheets of dolerite intrude into the sediments and basalts. Soils overlying the sedimentary and granitic rocks are generally sandy, while the basalt soils are shallow red and black clays.

In the Lebombo mountains, acid volcanics rise abruptly to form the steep slopes. Welded tuffs and other pyroclastics are present in the volcanics but there are few true lavas.

There are numerous mineral resources in Swaziland. Mineral production is concentrated around asbestos and coal.

LAND CLASSIFICATION AND LAND USE

The main soil types in the Highveld, Middleveld, and Lebombo regions are deep, acid, and freely drained red and yellow ferrisolic and ferralitic soils. Quartz stonelines underlie many soils. The natural fertility is low; however, these soils will yield well with adequate fertilizer and lime applications. Except for areas with steep slopes, the drainage, infiltration rates, and moisture-holding capacity of the soils are very good.

The lower Middleveld region soils are generally gray or red, light-textured soils obtained from granite or gneiss. The moisture-holding

capacity for rainfed cropping is restricted by the shallowness and light texture of the soil. Erodibility is high and fertility is low.

The western Lowveld region is underlain by sandstone and shale, has weathered to heavy textured clay-pan soils, and is characterized by poor drainage and high salinity. The region is sometimes overlain by poor moisture-holding light soils. The eastern Lowveld region is underlain by basalt which has weathered to red, brown, and black clays. Except for phosphorus, the soils are quite fertile and are characterized by poor drainage and high sodium and saline content.

In general, soils in the Lowveld region produce good yields if given sufficient moisture. They can be successfully irrigated with good intensive management.

Swaziland is divided into two land tenure systems--Swazi Nation Land (SNL) and Freehold Title Land (FTL), as shown on plate 3. SNL comprises approximately 60 percent of the total land area of Swaziland; FTL comprises the rest. Land use between the two tenure systems varies sharply and the figures presented here are for the country as a whole: grazing (natural-veld) - 60.7 percent; grazing (improved) - 5.5 percent; crops - 7.7 percent; fallow - 2.2 percent; other farmland - 4.9 percent; commercial forests - 5.5 percent; and all other land - 13.5 percent.

SNL is held in trust for the nation under the control of the King. Part of the land is allocated to the Swazi people for use as farming plots and homesites; the remainder is for communal grazing. Only Swazi Nation members are permitted to use SNL and the resources found on it. While the Swazi farmers have the land in crops, they have exclusive rights to that land, except the right to sell it. The Swazi landholders have user's rights to any communal land, water, or resources in the country. Most, however, remain in areas close to their homestead. A user may lose rights to the land, particularly if it is not kept in use

or if the user does not remain a member of the community. This lack of tenure poses some constraints to the adoption of "modern" farming practices.

FTL originated in 1907 when a British Government commission recommended that (1) the land concessions granted to foreigners by Swazi rulers be given the same status as the 99-1/3-year lease under the Roman-Dutch law of the Territory and (2) the holders be permitted freehold title to the land upon application. Most of these land concessions were converted to freehold title. In 1973, however, the Swazi National Council changed its ruling. Land still held under the original lease can no longer be converted to freehold title; when the 99-1/3-year lease period expires, this land will return to the ownership of the Swazi Nation.

Swaziland is basically a rural society; however, it has recently experienced significant industrialization and urbanization, especially in the Mbabane-Manzini area. The Mbabane-Manzini area is the center for government administration, residential areas, industries, and tourism. It is the most developed area in the country and needs careful planning for physical and environmental controls.

The urban area expansion has caused pollution problems because 50 percent of the urban shelters built annually are in squatter areas. In 1978, approximately 4,500 of the 14,600 shelters existing at the time were not durable and did not have access to potable water or have adequate sanitation.

VEGETATION

Swaziland has a rich variety of flora. The vegetation within each topographic region, however, is somewhat limited in variety and growth

because of the constraints of soil type and depth, moisture balance, climate, fire, exposure, and human impact.

In the Highveld region, the predominant vegetation is grass, composed primarily of sourveld grasses that are unpalatable for cattle. Large manmade forests of pine and eucalyptus cover about 80,000 ha in the northwestern and west-central areas of the Highveld region. Smaller areas of natural forest remain. These are comprised of the "wet" evergreen mountain or montane forests near or in the mist zone. Low temperatures and frost are the most limiting factors to vegetative growth.

The Middleveld region is a transitional zone between the distinct types of vegetation in the Highveld and Lowveld regions. Tall grasses and mixed brush are predominant; the grasses are usually sour. Forests have been eliminated by man in this region. Man's modifications, which are considered as limiting factors, are overgrazing, cultivation, and burning.

In the Lowveld region, the vegetation is predominantly bush and savanna, including natural "dry" forests. Broad-leaved savanna occurs in the west and thorn parkland and scrub occur in the east. The ground flora is comprised basically of sweetgrasses which are the foundation of the ranching industry. The limiting factor to vegetative growth in the Lowveld region is drought.

The Lebombo region has a predominantly mixed bush cover with tree cover on most of the steep slopes. Natural forests include small areas of "moist" semideciduous forests and "dry" forests. The grasses tend to be sweet. A notable number of rare plant species occurs in the Lebombo region. Rocky surfaces, as well as low rainfall, are the limiting factor to vegetative growth.

FISH AND WILDLIFE

The originally abundant wildlife population of Swaziland has steadily declined. During the first half of the century, the major cause of decline was hunting by foreigners; the present-day cause is the loss of wildlife habitat due to agricultural expansion. Wildlife is now very scarce in the wild. Presently, there are two wildlife sanctuaries and three nature reserves which protect about 42,650 ha of habitat. Proposed additions of 8 national parks, 5 nature reserves, 13 national landscapes, and 5 national wetlands would add approximately 121,830 ha to the existing protected area. The existing and proposed protected wildlife areas are shown on plate 4.

Several wildlife species are listed as endangered and threatened. Some of these are the scaly anteater, bontebok antelope, black-footed cat, cheetah, brown hyena, lechwe, mountain zebra, Nile crocodile, geometric turtle, and African elephant. In a survey regarding larger mammals, senior conservationists identified another 33 species as endangered, threatened, or rare. These include the lion, hippopotamus, black and white rhinoceros, wild dog, and about 18 antelope species. Some species that are present in greatly reduced numbers, outside the protected areas are:

- Ungulate (hoofed) animals - gray duiker, impala, blue wildebeest, greater kudu, vaal rhebok, steenbok, red duiker, oribi, reedbuck, waterbuck, and klipspringer;
- Predators - serval cats and jackals;
- Monkeys - a small number of vervets and chacma baboons;
- Crocodiles - at the point of extermination; and
- Hippopotamuses - only one group of 12 is known to exist.

Birdlife is abundant. Regionally rare species include the European stork, sacred ibis, and hadada ibis. Other more common species are the hammerhead, gray heron, widow bird, hornbill, and lilac-breasted roller. Species of egret, sunbird, weaver, and raptor are also present. There are significant numbers of waterfowl, especially in the Lowveld region at manmade lakes. Waders are common, sometimes in spectacular numbers.

A fisheries program using fish ponds has an excellent potential. There are 260 existing fish ponds and approximately three fish farms. Species used to stock fish ponds are mainly indigenous Tilapia and carp. Existing dams and rivers have a fishery potential which also appears good and is being explored. Government and industry are cooperating to develop fisheries in manmade reservoirs by using indigenous Tilapia, catfish, and yellowfish; perhaps bass will also be developed in the area.

Currently, there is a commercial fishing operation in the Sifunga reservoir which is located on the Ubombo Ranches sugar estate. The Simunye sugar estates are also planning a commercial fishery. In the Highveld region, the possibility of trout farming is being explored.

DEMOGRAPHY

The total estimated resident population of Swaziland in 1980 was 548,000. This resident population accounted for nearly 90 percent of the total population. The remaining population consists of Swazis living and working in other countries, primarily the RSA. Ninety-seven percent of the people are African, the majority of whom are Swazis. The population density per sq km is 30 for the country, 40 for SNL, 15 for FTL, and 396 for urban lands. The Middleveld region is most densely populated. In 1975, the birth rate was 49 per 1,000, with a projected population for the year 2000 of 900,000 people. Forty-eight

percent of the population is under age 15. The death rate is 22 per 1,000 and the life expectancy at birth is 46.5 years.

Swaziland's life expectancy rate of 46.5 years and infant mortality rate of 156 per 1,000 live births are significantly worse than those of other countries with similar average per capita incomes. Mother-child health problems, low immunization rates, social transition problems, and water-related diseases are contributing factors. The role of nutrition is yet to be determined.

The SNL supports 70 percent of the population, while 22 percent lives on FTL. The remaining 8 percent of the population resides in urban areas. Rural Swazis live in settlements of small family homesteads rather than in villages.

Most people depend on untreated surface waters that are not easily accessible and often harbor agents of disease. Schistosomiasis is a common debilitating disease. Gastroenteritis and dysentery are major child mortality factors. Malaria is also a common disease. Water development, therefore, would have important implications for combating or aggravating these water-related disease problems.

Schistosomiasis occurs in about 30 percent of the population. The prevalence of schistosomiasis is higher in the warmer Lowveld region than in the Highveld or Middleveld regions. It is also much higher near irrigation schemes because of the snail habitat made available by irrigation development. Canals, ditches, and other elements of irrigation would require designs and management specifically intended for snail control. Reservoirs would make chemical control of snails especially difficult.

Swaziland currently has a high population growth rate of 3.36 percent. Under the current land tenure system, this is placing pressure

on the land and other resources of the country. As a result, the government is promoting a family planning program.

Rural to urban area migration is increasing. In the 10-year period from 1966 to 1976, urban population in the Mbabane-Manzini urban corridor grew twice as fast as rural population. The expanding wage sector opportunities contributed to this rapid growth. Also, the attraction of RSA wage employment resulted in significant external migration. In 1978, 31 percent of the households in Swaziland had adult males who were working in the RSA.

Sixty percent of the Swazi people are Christian; the remainder follow the traditional animist religious beliefs.

The education of children is of primary importance to the Swazi adults. Many of the families that are engaged in subsistence agriculture sell their cattle to finance the education of their children. This is noteworthy because, in Swaziland, prestige is based on the ownership of large herds of cattle. The number of schools is increasing by 1.5 percent per year. The number of students is increasing by 3 percent and the teachers by 4.8 percent annually.

TRANSPORTATION AND COMMUNICATION SYSTEMS

The road system, railroad network, and airport are shown on plate 5.

A well-developed system of primary and secondary roads exists in Swaziland. Most roads are not paved; however, there is a good maintenance program throughout the country. The total length of all the roads in the system in 1978 was 2,653 km. Of this, approximately 54 percent was classified as main roads and 46 percent as district roads.

The railroad network has two main lines. An east-west railroad line (224 km) extends from the west-central portion of Swaziland to the Mozambique border. This line was primarily used to move iron ore. Recently, a new north-south line (94 km) connected the east-west line to Lavumisa at the southeastern corner of Swaziland.

Matsapha airport furnishes adequate airline transportation with nearby countries.

The bulk of Swaziland's external post and telecommunications services are dependent upon the RSA. There are 50 post offices in Swaziland that provide private boxes and house-to-house delivery. In 1978, there were 5,618 telephone connections, double the number of connections available in 1974. All major population centers in Swaziland have telephone communications.

ECONOMY

The economy of Swaziland is agriculturally based and export oriented. It is well diversified when compared to other African countries. The economy has a dualistic structure; there is a modern, mostly foreign-owned sector that is capital intensive and a traditional sector that is engaged in subsistence agriculture. Approximately 70 percent of the population is dependent upon the traditional agriculture sector. Maize is the major crop grown on SNL; however, an increasing amount of land is being used for cash crop production. The modern sector is made up of capital intensive agricultural industries, manufacturing industries that essentially process agricultural commodities, the lumber industry, the mining industry, and tourism.

Major export industries include the mining of asbestos; production of sugarcane, cotton, citrus crops, and pineapple; and production of

lumber and pulpwood. Government administration and agricultural production use the most labor. Approximately 37,000 ha of land are irrigated for production of export crops.

Two coal mines, the Mpaka and the Swaziland Colliery, are currently in operation. Depletions of high- and medium-grade iron ore reserves caused the closing of the Ngwenya iron ore mine near Oshoek. The three large sugarcane plantations are the SIS, the Big Bend estates, and the Simunye estates. Another plantation, the Malkerns estate, produces pineapple. The three large forestry production areas are the Usutu Pulp Company, the Piggs Peak Plantation, and the newly developed forestry area near Nhlangano in the southwestern part of the country. The Usutu Pulp Company, located in the western part of Swaziland, primarily produces pulpwood and the Piggs Peak Plantation, located in the northwest, primarily produces lumber. There is one asbestos mine, Havelock mine, which is located in the northeast near Bulembu. The tourism market consists of a major motel complex and casino in the Ezulwini valley southeast of Mbabane.

In the past, large "enclave"-type developments were promoted. As a result, a strong export-based economy has financed internal social programs. Currently, economic development planning should be concentrated on projects and developments that will create a need for greater work force participation.

EXISTING WATER RESOURCES DEVELOPMENT IN SWAZILAND

Existing water resources development in Swaziland (shown on plate 6) includes hydroelectric, irrigation, and municipal and industrial

water supply projects. Most of these projects utilize run-of-river flows with low head diversions. Existing diversion structures are listed in table I-1. Only one project, the recently constructed Mnjoli dam, includes significant onstream storage of 154 million cubic meters (mcm). The outlet works of this dam form the Ngomane diversion. Two irrigation projects have storage on minor streams. This storage is primarily used to store water diverted from large streams. Sand River reservoir has a storage capacity of 41 mcm and serves this purpose within the SIS. Three reservoirs--Pendora, Nyetane, and Sifunga--have a total storage capacity of 20 mcm and function similarly within the Big Bend estates area. A number of small diversion and pump-irrigation projects and numerous small farm ponds are also located in Swaziland.

Table I-1
Existing Diversion Weirs

Project	River Basin	Diversion Capacity (cubic meters/second)	Major Purpose
Ngonini	Lomati	2.0	Irrigation
Swaziland Irrigation Scheme	Komati	7.8	Irrigation
Mbabane	Mbuluzi	0.03	Municipal and Industrial
Ngomane	Mbuluzi	5.5	Irrigation
Simunye	Mbuluzi	6.5	Irrigation
Mkimkomo	Little Usutu	11.33	Hydropower
Malkerns	Upper Great Usutu	1.5	Irrigation
Edwaleni-Magadusa	Upper Great Usutu	3.7	Hydropower
Big Bend	Great Usutu	8.5	Irrigation
Nsoko	Ngwavuma	0.8	Irrigation

WATER-RELATED GOALS OF SWAZILAND

The GOS has set six goals for the development of its water resources. These goals are to:

- Maximize employment opportunities;
- Increase government revenue;
- Increase value added;
- Increase foreign exchange earnings;
- Import substitutions; and
- Protect and enhance the environment for the long-term benefits of the country.

The GOS is looking specifically toward the development of large-scale irrigation projects and the concomitant agribusiness to achieve these goals.

The current rapid rate of population growth has forced a major emphasis on the creation of job opportunities for the 8,000 to 15,000 new participants expected to enter the labor market each year. Industrial and commercial developments can reasonably be expected to provide only 2,000 to 3,000 new job opportunities per year. It is anticipated that agricultural development, through the use of irrigation, will keep some of these potential job seekers on the farm and provide related jobs in agribusiness as well.

Government revenues have kept pace with expenditures in the past. The significant upgrading in government services and the ambitious building program included in the Government of Swaziland's Third National Development Plan (Third National Plan) will require additional revenues to maintain a balanced budget. Some of these revenues could be provided by income taxes generated from the additional income created by irrigated agriculture.

Swaziland's exports generally consist of raw products and imports generally consist of finished products. The need for increased job opportunities, income, government revenue, and foreign exchange earnings has influenced the GOS to emphasize increases in value added in future economic growth. Irrigated agriculture provides an opportunity for increasing value added through the processing and marketing of agricultural products.

In the past, Swaziland was able to generate surpluses in foreign trade. The agricultural, mining, and forestry sectors maintained export earnings which offset purchases of energy and durable goods. The export of high-grade iron ore is now ceasing because of the depletion of known reserves. At the same time, there is an increasing demand for foreign goods. Increased forestry production for export cannot balance the situation because of the large requirements for the limited land and water. It remains then for the agricultural sector to increase its export potential to maintain or enhance foreign exchange earnings.

An item of increasing concern is the rapid growth in the importation of maize, dairy products, and other processed foods. Irrigated agriculture would allow domestic production of these products or substitute products. This would improve Swaziland's economic and political stability.

The environmental goal stems from a number of problems. The Library of Congress recently completed a Draft Environmental Profile of Swaziland which identifies five major environmental problems currently facing Swaziland. They are (1) soil erosion and degradation, (2) waterborne diseases, (3) the lack of an established system of protected areas, (4) shelter and environmental health problems associated with urbanization, and (5) the high rate of population growth.

On SNL, soil erosion and degradation result from cultivation and grazing. These are aggravated by the growth of both human and livestock populations. The results are pasture denudation and subsequent erosion, bush encroachment, springs drying up, siltation of reservoirs, and low animal productivity.

Waterborne diseases, particularly schistosomiasis (bilharzia), are a continuing health problem. The bulk of the rural population relies on untreated surface water and, because of this, approximately 30 percent of the population is infected with schistosomiasis. This problem is most severe in the Middleveld and Lowveld regions. Conditions in these regions are ideal for the spread of schistosomiasis and other waterborne diseases because of low stream velocities, warm water temperatures, and high population densities. The prevalence of schistosomiasis appears to be increasing with the development of irrigation even though control programs are underway in about a third of the irrigated areas.

Man's past and planned activities have caused and will continue to cause substantial modification of the natural environment. If the efforts to continue development of the country are to meet short- and long-term social and economic needs, it is important to establish an effective protected area system that will conserve the diversity and integrity of biotic communities of plants and animals within natural ecosystems.

Rapid urbanization of the Mbabane-Manzini corridor has led to significant shelter and environmental health problems. Suburban squatter settlements account for approximately 50 percent of the annual housing construction in the area. Many of these settlements are without access to potable water and most are without access to adequate sanitation facilities.

The high annual population growth rate of 3.36 percent is either the underlying cause of or is exacerbating these other serious environmental problems.

SURFACE WATER AVAILABILITY

Swaziland forms part of the eastern watershed region of southern Africa; the Lomati and Komati rivers originate in the RSA, flow through Swaziland, and discharge back into the RSA. The Mbuluzi river originates in Swaziland and discharges into Mozambique. The four major tributaries of the Great Usutu river originate in the RSA, combine to form the Great Usutu river in Swaziland, and discharge into the RSA and eventually into Mozambique. The Ngwavuma river rises in Swaziland and discharges into the RSA. Areas south of the Ngwavuma basin drain southward into the RSA through minor tributaries to the Pongola river. These rivers and their drainage basins are shown on plate 1.

The mean annual accruals in these rivers for seminatural, current, proposed, and potential conditions are shown in table I-2. All values are for the October through September water year. Current conditions are derived by subtracting the abstractions the RSA is currently making from the seminatural condition. Proposed conditions are derived by

Table I-2
Mean Annual Accruals
(mcm)

River	Inflow from RSA	Swaziland Accruals	Total Accruals
Lomati:			
Seminatural	78	135	213
Komati:			
Seminatural	660	280	940
Current (2 RSA Dams)	574	280	854
Proposed (3 RSA Dams)	426 1/	280	706
Potential (3 RSA Dams at Maximum Abstraction)	382 1/	280	662
Mbuluzi:			
Seminatural	0	352	352
Little Usutu:			
Seminatural	45	400	445
Upper Great Usutu:			
Seminatural	280	195	475
Current (1 RSA Dam)	240	195	435
Proposed (2 RSA Dams)	223 1/	195	418
Potential (2 RSA Dams at Maximum Abstraction)	148 1/	195	343
Ngwempisi:			
Seminatural	302	78	380
Current (2 RSA Dams)	265	78	343
Proposed (5 RSA Dams)	192 1/	78	270
Potential (5 RSA Dams at Maximum Abstraction)	85 1/	78	163
Mkondo:			
Seminatural	405	53	458
Proposed (2 RSA Dams)	266 1/	53	319
Potential (2 RSA Dams at Maximum Abstraction)	83 1/	53	136
Lower Great Usutu:			
Seminatural	0	178	178
Great Usutu System (Total):			
Seminatural 2/	1,032	904	1,936
Current (3 RSA Dams) 2/ 3/	955	904	1,859
Proposed (9 RSA Dams) 2/	726 1/	904	1,630
Potential (9 RSA Dams at Maximum Abstraction) 2/	361 1/	904	1,265
Ngwavuma:			
Seminatural	0	106	106

1/ Includes proposed RSA reserve for Swaziland from existing and proposed dams as follows:
Komati - 65 mcm/year reserve
Upper Great Usutu - 6 mcm/year reserve
Ngwempisi - 15 mcm/year reserve
Mkondo - 28 mcm/year reserve

2/ These totals include Little Usutu Seminatural.

3/ Total includes Mkondo Seminatural.

subtracting the abstractions which the RSA is planning to make from existing and proposed developments from the seminatural conditions. Potential conditions are derived by subtracting the maximum practicable abstractions that the RSA could make with existing and proposed developments from the seminatural conditions. Both the proposed and potential conditions include the amount of water which the RSA proposes to reserve for Swaziland from existing and proposed developments.

Approximately 75 to 83 percent of the total flow occurs in the summer months of October through March. A good portion of this summer runoff results from large storms. There is also considerable variation in flows from year to year. Considerable storage is required to utilize a significant portion of the flows shown in the table as total accruals. This is because of the seasonal and annual variations in flow together with monthly variations in demand.

GROUND WATER AVAILABILITY

No aquifers capable of providing volumes of water sufficient for irrigation have been identified. The regional water table is relatively deep and restricted by complex geology and compartmentation by dykes, faults, and veins. Perched water tables are common but are subject to great fluctuations depending upon the nature of the aquifer, the location, and the attitude. A complete assessment of the ground water resources has not been made. Such an assessment would be extremely difficult because of the complicated composition of the aquifers.

In spite of the difficulties inherent in aquifer research and assessment, such a program should be initiated because of the aquifers

potential for providing reliable small volume water supplies of good quality. These aquifers could provide rural domestic supplies to areas where the surface water is not potable or to areas distant from adequate surface supplies. Because there is no evidence that ground water is likely to play a role in major water resources development decisions, it is not considered further in this investigation; however, ground water may provide an opportunity for early implementation of large-scale irrigation projects.

WATER-RELATED PROBLEMS AND NEEDS

There are numerous specific water-related problems and needs, particularly in providing domestic water of adequate quality and quantity, throughout the country. A number of programs are underway to assess and resolve these problems and needs. The scope of this investigation did not include the identification, evaluation, or resolution of these specific water resources problems. A number of water-related problems and needs were, however, given a cursory review. This was done to determine if they were likely to influence major water resources development decisions either by requiring significant quantities of water or by providing substantial benefits for multiple-purpose water resources development.

MUNICIPAL AND INDUSTRIAL

Municipal and industrial (M&I) water demands were evaluated for six communities for which data were available--Mbabane, Manzini, Nhlangano, Piggs Peak, Hlatikulu, and Siteki. Average per capita consumption in these six communities is 250 liters per day. The highest per capita demand is in the Nhlangano system (338 liters per day) and

the lowest is in the Siteki system (183 liters per day). The Water and Sewerage Board has projected an increase in per capita demand by 1990. These demands are shown in table I-3.

Table I-3
Average Daily Per Capita Water Demand
1990

Community	Demand (liters)
Mbabane	323
Manzini	369
Nhlangano	446
Piggs Peak	314
Hlatikulu	287
Siteki	241
All others1/	235

1/ Includes: Havelock, Mhlume, Malkerns, Big Bend, Bunya, Mhlambanyati, Mpaka, Mankayane, Lavumisa, Tshaneni, and Ngwenya

The rates shown in table I-3 were multiplied by the high, medium, and low population projections for each community to determine future M&I water demands within each basin. Except for the Little Usutu basin, M&I water demands are negligible in terms of total annual volume requirements even if high population growth factors are projected as far as the year 2030 and return flows from M&I are ignored. The highest population projected for Nhlangano in the year 2030 (9,100) would require 1.5 mcm per year at the 1990 per capita demand of 446 liters per day. Only a portion of this would be consumed. Any amount less than 1 mcm per year is insignificant in this analysis. In the Little Usutu and Mbuluzi basins, however, the effect of M&I water demands is not negligible because of the growth potential of the two major population centers--Mbabane and Manzini. Assuming that the current high population growth continues and that 75 to 80 percent of the population is served by water and less than half by sewer, the

annual consumptive use could be as high as 7 mcm by the year 2000 and 22 mcm by the year 2030. On the other hand, if the birth rate and the rural to urban migration are effectively reduced after the year 1990 (a population growth rate in the Mbabane-Manzini area of 2.3 percent per year) and 96 percent of the population is served by water and over half served by sewer, water consumed by the M&I sector in the Little Usutu basin would be 4 mcm per year by the year 2000 and 8 mcm by the year 2030. Currently, a reserve of 13 mcm per year in the Black Mbuluzi river is being retained for Mbabane.

Although the water volumes required by M&I demands are not large enough to significantly affect major water resources development decisions, they should not be completely ignored in future planning. An appropriate reserve should be maintained in the Black Mbuluzi or the Little Usutu rivers, or both, for future M&I use for the Mbabane-Manzini area. The cost of providing adequate supplies to some M&I systems is quite high. Major water resources development may create an opportunity to provide these supplies at a lesser cost or with more reliability. Either situation would result in M&I benefits.

RURAL DOMESTIC

Rural domestic water demands include water required for homestead use as well as for livestock watering.

Human per capita water demand in rural areas varies depending upon availability of piped water. The Water and Sewerage Board standards for design of rural water systems indicate a demand of from 25 to 35 liters per capita per day. No data are available on the use rate of rural residents who do not have easy access to piped water. An assumption of 5 liters per capita per day was used for rural populations without access to piped water. These per capita demands were multiplied by rural population projections to determine future demands.

Based on this computation, total future annual human consumption in rural areas would be negligible when compared to water availability and water demands of the irrigation use sector. If, however, a future rural population of, for example, 1 million consumed 480 liters per capita per day, which is similar to some well developed rural areas in the United States, the total rural demand would be 175 mcm per year. This would be the equivalent of roughly 12,000 ha of irrigation demands across the country.

The livestock water demand is approximately 30 liters per head per day. This demand was multiplied by cattle populations projected at the same growth rate as during the 1973 to 1977 period. The total annual demand is negligible when compared to total water available and the water demands of the irrigation use sector.

There are at least four GOS programs that are making some progress in developing safe water supplies for rural Swazis. Irrigation development has the potential either to supplement these programs by providing safe domestic water supplies or to increase schistosomiasis by increasing snail habitat without providing potable water and snail control. It has been shown that irrigation is likely to greatly increase the prevalence of schistosomiasis, particularly of the more serious intestinal form, unless effective control is incorporated into the project.

Sanitation, health education, and potable water supplies are considered the three most needed elements in schistosomiasis control. Furthermore, safe water supplies would significantly reduce the prevalence of other serious diseases. Given this potential of irrigation both to harm and to benefit the health of the population, it seems that providing safe domestic water to all residents of an irrigation area would be imperative. As previously mentioned, the volume of water required for rural domestic water supplies would be minor compared to irrigation requirements.

Even though the volumes required for rural domestic water supplies are not currently large enough to affect major water resources development decisions, they could become significant in the future in some basins. There is also a potential for benefits in this sector resulting from major water developments. These benefits could be derived from improvements in the seasonal and geographical distribution of water.

ENERGY

The Swaziland Electricity Board (SEB) is responsible for providing all public supplies of electricity. Some large industrial concerns still generate a substantial portion of their own requirements under license from the SEB. Electrical requirements are currently provided by the Edwaleni Hydroelectricity complex supplemented with purchases from the South African Electrical Supply Commission (ESCOM) and diesel generation for peaking requirements. Between 1975 and 1979, total energy sales by the SEB increased from 126.3 gigawatt hours (GWh) to 222.8 GWh. The SEB capacity remained relatively constant throughout this period, while deficits were made up by purchases from ESCOM. Purchases from ESCOM increased from zero in 1973 to 96 GWh in 1978.

The maximum power demand generally occurs during the large irrigation pumping months of January through March. Since 1970, a secondary peak has become evident in midwinter because of the increasing use of electricity for heating.

Demands for energy are expected to be 256 GWh in 1980 and are projected to be 430 GWh by 1985 and 526 GWh by 1990. For the same time period, peak demand is projected to grow from 59 megawatts (MW) in 1980 to 91 MW in 1985 and to 112 MW in 1990. The SEB plans to meet this demand by construction of the Luphohlo-Ezulwini Hydroelectric Scheme, by continued purchases from South Africa, and by the possible construction of a coal-fired thermal plant near Mpaka.

Additional hydroelectric projects that would provide a total of more than 1 million GWh per year have been identified in previous studies. Presently, none of these projects can compete financially with the bulk electric supply from ESCOM. The Highveld region is particularly suited for providing peaking power but there is no current market or projected near future market for a significant amount of this type of generation. This leads to the conclusion that there is little prospect for hydroelectric generation in Swaziland in the near future. Because peak irrigation demands coincide with peak power demands, there does appear to be a potential for generating power with irrigation releases from any future irrigation storage reservoirs.

Water volumes are not likely to be significantly affected by energy production. Hydroelectric projects consume no water and can be designed and operated to enhance other use sectors. The potential coal-fired thermal plant near Mpaka would consume only 1 mcm per year.

MINING

Exploitable reserves of high- and medium-grade iron ore have been exhausted. Asbestos mining is expected to continue well into the 1980's and possibly longer. Recently proven good quality reserves of coal appear to offer the greatest future potential for mineral development. Newly proven reserves of tin and ceramic clay offer possibilities for small-scale mining and processing. Further investigation of old gold mining areas and two diamondiferous areas may result in additional possibilities.

The asbestos mine at Havelock and the existing coal mine at Mpaka use ground water for all their needs. If additional mining areas are developed, ground water will be the most likely source of water supply. Because the relationship between ground water and surface water is unknown and the volumes involved are very minor, the demands of the

mining sector are not expected to influence major water resources development decisions in any way. The likelihood that water resources development would create opportunities in this sector is also remote.

IRRIGATION

Irrigation is currently the largest consumer of water in Swaziland. Current and potential future requirements completely dwarf the requirements of other use sectors. It is the only use sector that has the potential of stressing the overall supply of water available. Table I-4 presents the number of hectares currently irrigated from each river and the annual irrigation consumptive use.

Table I-4
Average Annual Irrigation Consumptive Use
1979

River	Area Irrigated (hectares)	Application Rate1/ (meters)	Consumptive Use (million cubic meters)
Lomati	732	1.7	10
Komati2/	12,657	1.7-2.1	171
Mbuluzi3/	10,914	1.7-2.1	173
Little Usutu	150	2.0	3
Upper Great Usutu	3,261	1.7	45
Ngwempisi	591	1.7	8
Mkondo	251	1.7	3
Lower Great Usutu	10,840	2.1	185
Ngwavuma	2,609	1.7-2.1	31
Total	42,005		629

1/ Highveld and Middleveld - 1.7 meters (1.4 meters consumptive); Lowveld - 2.1 meters (1.7 meters consumptive)

2/ Most of the area irrigated is within the Mbuluzi basin. 171 mcm represents total diversion rate. Consumptive use is actually 103 mcm.

3/ 1983 projection

Most of the current consumptive use of the Lomati river water occurs on the Ngonini estate. The largest water user of the Komati river is the SIS. Most of the SIS lies within the Mbuluzi river basin. Most of the water use in the Mbuluzi river basin occurs on two sugar estates downstream from the confluence of the Black and White Mbuluzi rivers and in the developing Ngomane scheme. Approximately 6 mcm is used in upstream areas. In the Upper Great Usutu basin, the largest water user is the Malkerns estate. The major consumptive users in the Lower Great Usutu basin are the sugar estates in the Lowveld region. Approximately 14 percent of the use is by small riparian users. The major user in the Ngwavuma basin is the sugar estate at Nsoko.

Future irrigation potential was evaluated in the "General Plan for Development and Utilization of Water Resources" (1970 UNDP Report). The evaluation was based, in part, on the National Soil Reconnaissance Map and its attendant Capability Map and on some detailed and semi-detailed capability maps that had been prepared for areas that were considered to have good irrigation potential. The areas identified in the 1970 UNDP Report that have not yet been developed for irrigation are shown in table I-5.

The National Soil and Land Capability Maps were examined during this investigation to determine the maximum potential for irrigation. In order to do this, a liberal approach was used in identifying land considered suitable for irrigation. Accordingly, land which could be irrigated by either overhead or furrow systems in considered irrigable, including land with slopes as great as 14 percent. Poorer quality soils have also been included, even though most of these need intensive agricultural practices in order to make them productive. These soils are currently being irrigated successfully in the Lowveld region.

Table I-5
Remaining Irrigation Development Potential as of 1980
1970 UNDP Report

Basin	Irrigable Area in Hectares				Annual Consumptive Use (mcm)
	Highveld	Middleveld	Lowveld	Total	
Lomati	0	486	0	486	6
Komati	0	0	4,050	4,050	44
Mbuluzi	0	0	13,365	13,365	160
Little Usutu	0	6,900	0	6,900	14
Upper Great Usutu	0	2,415	0	2,415	9
Ngwempisi	2,835	0	0	2,835	21
Mkondo	0	405	0	405	0
Lower Great Usutu	0	0	18,225	18,225	208
Ngwavuma1/	0	0	2,530	2,530	30
Total	2,835	10,206	38,170	51,211	492

1/ Identified in Ngwavuma River Basin Study, Swaziland, February 1977

Since there were fewer constraints to determining irrigable soils in this study than in the 1970 study, this report identifies more land as potentially irrigable than did the 1970 UNDP Report. It is recognized that a significant portion of the soils identified as potentially irrigable will eventually prove to be unsuitable for irrigation. Further investigation of specific irrigation schemes will have to include more detailed soil analysis.

Table I-6 identifies the amount of land considered as potentially irrigable in each basin. The identification of irrigable lands was based on land capability only and did not consider water availability. This examination, therefore, identified much more land as irrigable than could ever be irrigated by the available water in Swaziland. These lands are shown on plate 7. In the Lomati basin, the soils along the left bank have the highest soil suitability rating. The soils along the right bank are generally classified as average or poor. The

Table I-6
Maximum Additional Irrigation Development Potential

Basin	Irrigable Area in Hectares Highveld	Middleveld	Lowveld	Total	Annual Consumptive Use (mcm)
Lomati	0	16,148	0	16,148	121
Komati	0	5,934	40,604	46,538	531
Mbuluzi1/	251	1,613	29,136	31,000	344
Little Usutu	5,110	9,439	0	14,549	109
Upper Great Usutu	1,899	3,899	0	5,798	43
Ngwempisi	8,397	0	893	9,290	74
Mkondo	1,395	4,867	0	6,262	47
Lower Great Usutu	0	0	37,700	37,700	452
Ngwavuma	5,033	0	23,304	28,337	318
Total	22,085	41,900	131,637	195,622	2,039

1/ After full planned irrigation at Ngomane

irrigation potential of land adjacent to the upstream one-third of the Lomati river is considered to be limited.

In the Komati basin, most of the irrigation potential is in the Lowveld region. There are some small areas adjacent to the river in the Middleveld region which could be irrigated on a small scale. There is opportunity for major irrigation development on either bank. The soils, however, are poor for the most part and would require intensive management. There is a narrow band of good soil adjacent to the lower half of the river reach.

In the Mbuluzi basin, there are some small areas adjacent to the Black Mbuluzi river in the Highveld region and several areas in the Lowveld region along both the Black and White Mbuluzi rivers which are potentially irrigable. Most of the potentially irrigable land in the Lowveld region is downstream from the new Mnjoli dam. The vast majority of this land is classified as poor soil and would require intensive

management. Some of the soils will have to be surveyed carefully for depth limitations as they are characteristically quite shallow. The best soils lie east of the existing Vuvulane scheme. There is also a large tract of good soil along the Nkhalashane river in the Lebombo region north of the Mbuluzi river.

In the Little Usutu basin, there are several areas adjacent to the river in the Highveld region that have good soil and are potentially irrigable. The best soils in the basin, however, are in the lower Mtilane basin and the lower Little Usutu basin. These were identified in the 1970 UNDP Report as being irrigable.

In the Upper Great Usutu basin, there is limited irrigation potential. Two small areas adjacent to the river offer the best potential. One area is upstream from the confluence of the Dudusi river and the other area is opposite Malkerns estate.

In the Ngwempisi basin, there are several potentially irrigable areas adjacent to the river in the Highveld region upstream from the Ngwempisi Gorge. The majority of these soils are average and the best soils are located immediately adjacent to the river. Some of the average soils may be too shallow for irrigation. There are just a few areas downstream from the gorge which are potentially irrigable; these areas are located just upstream from the confluence of the Ngwempisi and Usutu rivers.

In the Mkondo basin, there is a large area along the Motane river and another large tract of land adjacent to the middle reach of the Mkondo river through its center reach which are potentially irrigable. The Motane area is comprised mostly of good soils while the Mkondo area has both good and poor soils.

By far the largest area of potentially irrigable land is in the Lower Great Usutu basin. Generally the soils in this area are average or poor with some good soils scattered throughout. The best soils exist in the Mapobeni area. The soils south of the Usutu river are generally better than those north of the Usutu river.

The largest tract of good to excellent soils in the country lies south of the Ngwavuma river in the eastern Lowveld region. There are two other fairly large tracts of potentially irrigable land in the Middleveld region of the Ngwavuma basin. One tract is in the vicinity of the confluence of the Nsongweni river and the other is upstream from the confluence with the Mantambe river.

PHYSICAL AND CHEMICAL WATER QUALITY

For several years, the GOS has regularly sampled 37 stream sites for water quality data. The parameters tested include pH, turbidity, alkalinity, and hardness. Domestic water supplies and treated sewage are also sampled. Based on these tests, it can be said that Swaziland's water quality is quite good.

The pH ranges from 6.1 to 8.9 and averages about 7.2. This is a slightly low range. Domestic or irrigation use would require noncorrosive pipes or treatment to avoid metal corrosion by water with pH's below 7.0. Water with a pH below 6.0 could pose some limits to the success of bass fisheries in the country. Also, certain toxic substances become more toxic under low pH conditions. Otherwise, the pH should not pose significant constraints to use.

Turbidity ranges from zero to 300 Formazine Turbidity Units (FTU's) and averages about 16 FTU's. During high flows, turbidity can become the worst water quality problem. Soil which washes from fields and burned and overgrazed areas can make streams too turbid for aquatic

populations and can accelerate reservoir sedimentation. The naturally low turbidity during low flows, however, indicates that turbidity would otherwise pose no constraints to use.

Alkalinity and hardness have recorded values which fall well within acceptable limits and pose no constraints to use of the water.

The capacities of sewage treatment facilities are frequently stressed, particularly during low rainfall periods. Industrial discharges have caused water quality problems in the past and such problems could increase as industrial development grows. Rural nonpoint runoff is a potential source of pollution, especially from pesticides and herbicides. The degree of such pollution is currently unknown.

Additional study of water quality seems justified in Swaziland. The possible constraints of low pH's should be determined in specific areas. Seasonal turbidity problems may need to be evaluated and monitored in fishery areas or in areas upstream from reservoirs. Industrial and agricultural runoff should be monitored to avoid new, potentially serious problems.

RECREATION AND TOURISM

Swaziland's tourism industry is currently concentrated in the casino-resort center of the Mbabane-Ezulwini area. The GOS's policy is to diversify and decentralize the industry. Reservoirs could facilitate this by providing recreational opportunities and tourist attractions in other parts of the country.

The number and duration of visits to Swaziland has declined in recent years but could be boosted with the help of new attractions at manmade reservoirs. Waterbirds could become abundant and serve as an attraction to visitors, and sport fisheries could become significant

stimulants to tourism. Further, water development could contribute to the infrastructure needed for managing national parks and nature reserves. The development of these protected areas could also help increase the rate of tourism. In addition, activities such as boating, swimming, and waterskiing could add to the enjoyment of visitors in Swaziland.

In order for such developments to aid the tourism industry, other developments such as roads and boat ramps may be necessary. Also, water contact recreation would require efficient schistosomiasis control.

FISH PRODUCTION

Swaziland's goals of economic independence can be facilitated by the development of food fisheries in the country's rivers and reservoirs. Water quality in the rivers is apparently good and has a high potential to support fisheries. These rivers need an investigation to determine their status and potential, management to develop their fisheries, and protection to preserve their value to the nation. Water resources development could cause potential harm to rivers by impoundment of running waters, creation of low flows, or introduction of harmful waste waters. Water development could also offer benefits by providing for guaranteed flows to important fisheries.

Manmade reservoirs could offer considerable benefits by greatly expanding lake habitat for fisheries. Tilapia, yellowfish, catfish, and other fish show potential to produce harvestable yields in such reservoirs. In order to realize their potentials, these reservoirs would need management and protection. The GOS could not be expected to closely manage such potentially large fisheries. The fish populations should be considered in the design and operation of the reservoirs to avoid stifling populations. Further, such fisheries would need public access if Swazis are to reap a real benefit.

It is unlikely that fishery development would have any significant effect on water development, except that some fisheries could require guaranteed water levels during all seasons. This could entail design and operation considerations in water project development.

FLOOD CONTROL

There is very little existing information on flood conditions. There are no records of damages and little information on floodflows and elevations. Field observations indicate that the flood plain damage potential is limited to a few roads and bridges, diversion and canal systems, and agricultural lands. Reservoirs with flood storage capacity would tend to reduce these damages. More intensive use of the country's land and water resources would generate pressure for more intensive development of flood hazard areas. An effective flood plain management program should be developed to assure appropriate flood plain use in the future.

PRELIMINARY PLAN FORMULATION

This portion of the report presents the results of the preliminary plan formulation analysis performed during the study. The analysis was conducted in sufficient detail to determine potential plans or concepts which should be examined in greater detail.

PLANNING ASSUMPTIONS AND CONSIDERATIONS

The scope, costs, and effects of the potential plans presented in this section are highly dependent on the planning assumptions and

considerations which were used during the plan formulation analysis. The scope of the potential plans was particularly affected by two factors--assumed RSA abstractions and the effects of the length of streamflow records on water availability. These two factors resulted in a generally conservative estimate of additional irrigation potential in Swaziland. These two factors, and other plan formulation considerations, are discussed in the following paragraphs.

The RSA has developed a plan for the construction of an additional seven dams on rivers upstream from Swaziland. In this plan, the RSA presents its estimated water abstraction needs from these dams. The RSA also proposes to reserve specified flows for Swaziland from these dams. As presented in the Supply-Demand Analysis, it has been determined that the RSA could abstract more than its estimated needs and still reserve the specified flows for Swaziland. These larger abstraction rates are identified as maximum practicable abstractions and are defined as those abstractions that could be made without exceeding a shortage index of 0.25.

For purposes of plan formulation, it was assumed that the RSA would abstract water from its existing and proposed dams at the maximum practicable abstraction rate while reserving the specified Swaziland flows. If RSA abstractions remain at the estimated abstraction needs, however, there would be more water available for irrigation in Swaziland than is presented in this plan formulation section. These are, therefore, opportunities for further expansion of irrigation in Swaziland beyond the plans presented in this section. This is particularly apparent in the Usutu river basin where the RSA maximum abstractions used in plan formulation are more than twice the RSA's estimated abstraction needs.

The potential plans presented in this section were developed by first determining the amounts of water which could be abstracted for irrigation at a given site without storage. The same site was then

analyzed to determine the amount of water which could be abstracted for irrigation with storage. The difference between the abstractions with storage and without storage was assumed to be the amount available for additional irrigation from that site.

This may understate the amount actually available for additional irrigation with construction of storage facilities. The identification of water available for irrigation for without storage conditions is highly dependent on the streamflow record length. As shown in the Supply-Demand Analysis, using the relatively short streamflow records available in Swaziland (except for the Komati river) to determine water availability without storage may result in overstating the actual amount available by as much as 95 percent. Under with storage conditions, this analysis is much less affected by the length of record. More detailed analysis is required; however, it is apparent that the difference between water availability with and without storage is greater than has been determined by using the short streamflow records. This would not affect total additional irrigation in Swaziland. It would, however, result in greater economic feasibility for those plans which include construction of storage facilities.

The plans which were developed and which are presented here are for irrigation purposes. Some attention was paid to the possibility of multiple-purpose use of potential plans but the primary emphasis was placed on irrigation. Of the 17 damsites analyzed during this study, three have been identified as having significant hydropower potential. All of these sites may have limited hydropower potential, however, and future analysis of any of the plans identified in this study should, at the very least, investigate the inclusion of small hydropower facilities to provide the power needs of the potential irrigation project.

Other multiple-purpose uses, such as recreation and development of fishery industries, should be examined during future studies of any of

these plans. Because the potential dams would be operated to meet irrigation needs, however, the drawdown of the reservoir may limit these types of uses.

Municipal, industrial, and rural domestic water supplies are potential uses that should be examined during future studies. These were not examined in depth in this study because the amounts of water required for these uses represent a very small proportion of the irrigation requirements for all areas except the Little Usutu basin. The Mbabane-Manzini urban corridor is located in this basin. Assuming a continued high population growth rate for this urban corridor, annual water supply demands could be as high as 22 mcm by the year 2030. This demand could be shared by the Little Usutu and Mbuluzi rivers. Although this study did not analyze any additional irrigation plans in this basin, the potential water supply needs of this urban corridor should be examined in ongoing project planning. For the remaining areas, any potential plans could more than meet water supply needs in the surrounding area with little impact on the potential irrigation demands.

The amount of land irrigated under each plan does not represent the total amount of land required for the project. Additional lands would be required for homestead roads, canals, and project facilities. Generally, this amounts to about 10 percent of the irrigated lands.

The potential damsites examined in the study are shown on plate 8. Plate 7 shows all potential irrigable lands.

The effectiveness of each potential plan in meeting the water-related goals of Swaziland was evaluated. Quantification of these effects was possible in some instances, such as the number of jobs created by a given plan. In most cases, however, these effects are not directly quantifiable. The general magnitude of these effects can be inferred from the total costs and net irrigation benefits associated

with each plan. Effects on water-related goals such as increased government revenues, increased value added and foreign trade earnings, and import substitution depend on other factors and on other activities in addition to increases in agricultural production. In some instances, significant additional costs would be incurred in meeting these goals, such as the construction and operation of additional processing facilities to meet the goal of increasing value added. No attempt was made to quantify these impacts.

Impacts on the natural environment can be quantified to a certain extent. Conversion of land from its existing use to intensive agricultural production would reduce the quality of wildlife habitat. This would be partially offset by the construction of a reservoir, thereby creating aquatic habitat. Other impacts on the environment would include the disruption of wildlife movement by construction of canals.

Some costs of developing a large irrigation project are not included in the costs presented for each plan. These costs would include such items as the construction of homesteads for the project farmers, the development of roads, the construction of maintenance and storage facilities, and the costs of administering the project.

Plan formulation was conducted on a basin-by-basin basis. This formulation is presented in the following paragraphs.

LOMATI

There are currently 732 ha under irrigation in the Lomati basin. The current annual water demand is about 13 mcm. Most of this demand is for the Ngonini estates; water is diverted from a weir located near gage station 11. The Supply-Demand Analysis indicates that a total of 47 mcm could be supplied at the Ngonini diversion with no storage in the basin. This exceeds the current demand by 34 mcm.

This surplus would be sufficient to irrigate an additional 3,600 ha. About 18,000 ha of potentially irrigable lands have been identified in the Lomati basin.

Two potential storage sites have been identified. Damsite (DS) 5.1 would be located on the Lomati river approximately 12 km downstream from the Swaziland-RSA border; DS 5.2 would be located near gage station 11.

DS 5.2 was the only site in the Lomati basin that was evaluated in this study because it would allow for greater control of the Lomati river flows and could provide more than twice the storage capacity that could be provided by DS 5.1. Several reservoir sizes were examined for DS 5.2. A comparison of the total cost-versus-acres irrigated indicates that the cost per acre irrigated would be lowest for a reservoir capacity of about 160 mcm. — NEED YIELD OF 148 mcm

Two plans have been identified for the Lomati basin. The first plan would consist of irrigation in the Lomati basin without the development of storage capacity. The second plan would consist of two components--the development of DS 5.2, and a diversion upstream from DS 5.2 using run-of-river flows.

The no-storage plan would include the construction of a diversion weir on the Lomati river about 15 km upstream from gage station 11 at an approximate elevation of 530 meters m.s.l. A total of 3,600 ha on the left bank would be irrigated under this plan. While there are 12,000 ha of irrigable land on the right bank, this land would be somewhat more costly to develop for irrigation. This plan would include a main delivery canal from the diversion weir; the canal would be 42 km in length and would have a capacity of 3 cubic meters per second (cms). An economic summary of this plan is shown in table I-7.

Table I-7
Lomati Basin
Economic Summary
No-Storage Plan

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Diversion			250,000
Main Delivery System	42 km	105,024	4,411,000
Distribution System	3,600 ha	719	2,588,000
Land Preparation	3,600 ha	588	2,116,000
General Drainage	3,600 ha	210	756,000
Total Construction Costs			10,121,000
Interest During Construction			1,619,000
Annual Operation and Maintenance			818,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	3,600 ha	1,569	5,648,000
Annual Net Revenues without Irrigation	3,600 ha	235	846,000
Productivity Loss	25 ha	235	6,000
Net Irrigation Benefits			4,796,000
INTERNAL RATE OF RETURN (50 YEARS), PERCENT			33

This no-storage plan would result in the creation of about 1,800 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 3,600 off-farm jobs. About 300 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide about 1,400 homesteads with an annual income of E3,900. All of the lands irrigated under this plan would be SNL.

The storage plan would include irrigation from DS 5.2 plus irrigation from a diversion weir located 15 km upstream from DS 5.2. Under this plan, approximately 14,200 additional ha in the basin would be irrigated. DS 5.2 would supply the existing downstream irrigation requirements of 13 mcm per year at the Ngonini diversion and would supply water for an additional 9,200 ha. This plan would also include a diversion weir upstream from DS 5.2 at the same location as the diversion in the no-storage plan. This diversion weir would be capable of providing sufficient water to irrigate 5,000 ha. More land can be irrigated from this diversion location than under the no-storage plan diversion location because the Ngonini diversion requirements would be met from storage at DS 5.2.

The upstream diversion component would include two diversion works with a total of 85 km of main delivery canals. The canals would have a capacity of about 4 cms. The 5,000 ha irrigated by this component would be located on the right bank of the Lomati river. About 300 ha of this total would require field tile drainage facilities. The right-bank lands were chosen because they are less densely settled and the social impacts associated with resettlement would be less severe than they would be if the left bank lands were irrigated.

DS 5.2 would be approximately 55 meters high and would have a total storage capacity of 160 mcm. This component would include a diversion at the damsite to irrigate 2,800 ha on the left bank and

6,400 ha on the right bank of the Lomati. This component would include about 85 km of main delivery canals. About 150 ha of the left-bank lands and 1,750 ha of the right-bank lands would require field tile drainage facilities. The left-bank canal would have a capacity of about 2 cms and the right-bank canal capacity would be about 5 cms.

An economic summary of this plan is shown in table I-8.

Table I-8
Lomati Basin
Economic Summary
With Storage Plan

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Dam			16,000,000
Upstream Diversion			250,000
Main Delivery System	170 km	(127,500 ave)	21,674,000
Distribution System	14,200 ha	719	10,207,000
Land Preparation	14,200 ha	588	8,348,000
General Drainage	14,200 ha	210	2,981,000
Field Tile Drainage	2,200 ha	1,131	2,489,000
Total Construction Costs			61,949,000
Interest During Construction			9,912,000
Annual Operation and Maintenance			3,307,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	14,200 ha	1,569	22,280,000
Annual Net Revenues without Irrigation	14,200 ha	235	3,337,000
Productivity Loss	1,270 ha	235	298,000
Net Irrigation Benefits			18,645,000

INTERNAL RATE OF RETURN (50 YEARS), PERCENT 21

This plan would result in the creation of about 7,000 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 14,000 off-farm jobs. About 1,400 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide about 5,700 homesteads with an annual income of E3,900. All of the lands irrigated under this plan would be SNL.

This plan could be developed in stages. Either component could be implemented first, although implementation of the upstream diversion component could be accomplished in a relatively shorter time period.

Significant opportunities exist for irrigation in the Lomati basin without storage. Detailed future studies should examine this potential and the potential for staged development of irrigation with storage at DS 5.2.

It should be noted that implementation of either of these plans would use water which is currently allowed to flow through Swaziland and then used in the RSA. The size of these plans could be reduced to allow a specified reserve for the RSA when agreement on this reserve is reached.

Although both plans have relatively high internal rates of return, the without storage plan rate of return may be reduced and the with storage plan rate of return may be increased, depending upon further analysis. This is a result of the uncertainties related to water availability versus length of record, as shown under the planning assumptions and considerations portion of this section.

The main delivery system costs presented in tables I-7 and I-8 may be reduced. The canals follow the contours surrounding the area to be irrigated and are, thus, fairly long canals. The costs may be reduced

by using siphons and tunnels to shorten the length of the canals. A trade-off analysis should be performed during detailed planning to determine if the costs of the siphons and tunnels would be less than the costs of long canals.

KOMATI

Current irrigation demands in the Komati basin total approximately 171 mcm per year. Most of this demand is for the SIS for irrigation in both the Komati and Mbuluzi basins. Most of the return flows from the SIS discharge into the Mbuluzi river. In addition to these irrigation demands, a total of 3 mcm per year must be discharged at the SIS weir to meet the downstream flow requirements at the South African border.

The impacts that would occur on the SIS irrigation demands if the RSA constructs Hooggenoeg dam on the Komati river in addition to the two existing RSA dams was examined in the Supply-Demand Analysis. This analysis indicates that, with all three dams in operation, flows at the SIS weir would be able to meet only about 45 percent of the existing demand. Under these conditions, the SIS could experience an average deficit of 93 mcm per year, compared to a shortage of about 15 mcm per year under existing conditions. The 93 mcm per year shortage would be even more severe without the proposed RSA reserve from these three dams.

Thirteen damsites have been identified in the Komati basin. As shown in the Damsite Screening Section, five of these sites were selected for examination in this study. The sites are DS 6.2D, located on the Komati river about 10 km downstream from the RSA border; DS 6.5, located on the Komati river about 30 km upstream from the SIS weir; DS 7.1, located on the Mkomazane river about 10 km upstream from its confluence with the Komati river; DS 7.2, located on the Mlambongwenya river about 4 km upstream from its confluence with the Komati river;

and DS 7.3, located on the Mzimnene river about 10 km upstream from its confluence with the Komati.

Analysis of storage capacity-versus-net assured draft indicates that a system of reservoirs at DS 6.2D, DS 7.1, DS 7.2, and DS 7.3 would not be capable of replacing the SIS demand shortage with all potential RSA reservoirs in operation. The only site with sufficient yield potential to replace this shortage would be DS 6.5. Replacement of this shortage would require that DS 6.5 be constructed with a storage capacity of 75 mcm; the total cost would be more than E15 million.

The uncertainties associated with the construction and operation of additional RSA dams would dictate that the development of additional irrigation in the Komati basin be postponed until these uncertainties are resolved. If the RSA constructs these dams, the alternatives would be the construction of DS 6.5 or an agreement between Swaziland and the RSA to share the SIS shortages. If the RSA reservoirs are not constructed, an additional 6,000 ha could be irrigated in the Komati basin with construction of DS 6.5 and DS 7.3.

MBULUZI

There are about 6,000 ha in the basin which are irrigated from the Mbuluzi river. Mnjoli dam, located on the Black Mbuluzi river about 10 km downstream from gage station 3, will increase total irrigated land to 10,914 ha by 1983. There are two major irrigation areas in the basin which use Mbuluzi river flows. The Simunye area requires approximately 118 mcm per year from its diversion weir which is located immediately downstream from the confluence of the Black and White Mbuluzi rivers. The Ngomane area will require 103 mcm per year from Mnjoli dam by 1983.

The Supply-Demand Analysis indicates that an additional 76 mcm per year could be supplied to the Ngomane area from Mnjoli dam. This would be sufficient to irrigate an additional 5,000 ha in the Mbuluzi basin.

Ten potential damsites have been identified in the Mbuluzi basin. One of these sites, Mnjoli dam, has been constructed. As shown in the Damsite Screening Section, one site was chosen for examination in this study. This is DS 8.4 and it is located on the Black Mbuluzi river about 30 km upstream from gage station 3.

Analysis of DS 8.4 indicates that an additional 1,200 ha could be irrigated from this dam. The cost per hectare irrigated, however, would be exceedingly high, nearly E15,000 per hectare for the dam costs alone. This results from the fact that most of the irrigation water that can be taken from storage on the Black Mbuluzi river is already controlled by Mnjoli dam. Construction of a considerably larger dam, such as DS 8.4, therefore, would not yield a correspondingly large increase in additional irrigation.

The obvious plan for developing additional irrigation in the Mbuluzi basin consists of using the additional water available from the Mnjoli dam. With the Ngomane irrigation project in full operation, Mnjoli dam could still provide for the irrigation of an additional 5,000 ha.

There are about 31,000 ha of additional irrigable lands in the basin. Of this total, approximately 20,000 ha could be reached by a diversion weir and canal from Mnjoli dam. It may be possible to extend the existing Ngomane canal for this additional irrigation. For purposes of this report, an entire new diversion and canal were evaluated. The possibility of extending the existing canal should be examined, however, if this plan is studied in more detail.

This plan would consist of a diversion weir and canal to irrigate 5,000 ha in the area adjacent to the existing Ngomane irrigation project. The canal would be approximately 117 km in length with a capacity of 7 cms. An economic summary of this plan is shown in table I-9.

Table I-9
Mbuluzi Basin
Economic Summary
Additional Irrigation from Mnjoli Dam

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Diversion			300,000
Main Delivery System	117 km	147,555	17,264,000
Distribution System	5,000 ha	719	3,595,000
Land Preparation	5,000 ha	588	2,940,000
General Drainage	5,000 ha	210	1,050,000
Total Construction Costs			25,149,000
Interest During Construction			4,023,000
Annual Operation and Maintenance			1,181,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	5,000 ha	1,569	7,845,000
Annual Net Revenues without Irrigation	466 homesteads	30	14,000
Productivity Loss	125 ha	0	0
Net Irrigation Benefits			7,831,000

INTERNAL RATE OF RETURN (50 YEARS), PERCENT 23

This plan would result in the creation of about 2,500 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 5,000 off-farm jobs. About 500 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide about 2,000 homesteads with an annual income of E3,900. All of the lands irrigated under this plan would be SNL.

This plan would have a very high internal rate of return. This is due to the fact that no additional storage reservoirs on the Mbuluzi river would be required, while a considerably large amount of land could be irrigated.

A westward expansion of the existing Hlane Game Sanctuary has been proposed for inclusion in the proposed Hlane National Park. About 20 percent of the lands that would be irrigated under the plan are within the proposed Hlane expansion. This potential conflict would need to be examined in any future studies of this plan.

Detailed future studies should be conducted to more accurately determine the additional irrigation potential of Mnjoli dam.

The canal costs associated with this plan may be reduced by using siphons and tunnels. A trade-off analysis should be performed during detailed planning.

A detailed analysis of streamflow versus abstractions should be performed to more accurately determine the additional irrigation potential. Analysis of potential water conservation measures in conjunction with implementation of the Ngomane Irrigation Scheme should be performed to determine if this would further increase potential additional irrigation from Mnjoli dam.

NGWAVUMA

There are currently 2,600 ha under irrigation in the Ngwavuma basin. This represents a demand of 39 mcm per year for irrigation. Most of this demand is for irrigation at the Nsoko diversion. The Supply-Demand Analysis indicates that this demand cannot be met under existing conditions. There is a current annual shortage of 14 mcm for irrigation in the basin.

One damsite was identified during this study. DS V would be located on the Ngwavuma river just upstream from the Nsoko diversion. DS V could provide about 54 mcm per year if constructed with a storage capacity of about 150 mcm. This would provide enough water to make up the existing shortage at the Nsoko diversion and to irrigate an additional 2,400 ha.

The plan to irrigate the additional 2,400 ha would include DS V plus a diversion at the damsite to divert water into a canal. DS V would be approximately 35 meters high. The canal would be approximately 39 km in length and would have a capacity of about 2.5 cms. It would irrigate 2,400 ha on the right bank of the Ngwavuma river. Table I-10 presents an economic summary of this plan.

This plan would result in the creation of about 1,200 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 2,400 off-farm jobs. About 130 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide about 1,000 homesteads with an annual income of E3,900. Only a small fraction of the lands irrigated under this plan would be SNL.

This plan would provide significant benefits to Swaziland. There are, however, approximately 38,000 potentially irrigable hectares in

Table I-10
Ngwavuma Basin
Economic Summary
Damsite V Plan

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Dam and Diversion			9,000,000
Main Delivery System	39 km	97,487	3,802,000
Distribution System	2,400 ha	719	1,726,000
Land Preparation	2,400 ha	588	1,411,000
General Drainage	2,400 ha	210	504,000
Total Construction Costs			16,443,000
Interest During Construction			2,631,000
Annual Operation and Maintenance			591,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	2,400 ha	1,569	3,766,000
Annual Net Revenues without Irrigation	100 homesteads	30	3,000
Productivity Loss	30 homesteads	30	1,000
Net Irrigation Benefits			3,762,000

INTERNAL RATE OF RETURN (50 YEARS), PERCENT 17

the Ngwavuma and Pongola basins. Although these lands are some of the best irrigable soils in the country, flows in the Ngwavuma river are not sufficient to irrigate more than a small portion. For this reason, a large transbasin diversion was examined to import water from the Great Usutu system into the Ngwavuma and Pongola basins. This plan is examined in the section on the Usutu system.

Detailed future studies should be conducted to more accurately determine the irrigation potential of DS V. The economic feasibility of this plan may be improved during detailed planning with an analysis of abstraction rates versus streamflow record length as outlined in the planning assumptions portion of this section.

USUTU SYSTEM

The entire drainage area of the Great Usutu river in Swaziland was considered as one system in plan formulation. This area will be called the Usutu system to avoid confusion. This area is composed of five major drainage basins--the Little Usutu, Upper Great Usutu, Ngwempisi, Mkondo, and Lower Great Usutu basins.

There are currently about 15,000 ha of land irrigated in the Usutu system. Over 65 percent of the irrigated areas is in the Lower Great Usutu basin and over 20 percent is in the Upper Great Usutu basin. The remainder is scattered throughout the Little Usutu, Ngwempisi, and Mkondo basins. The largest irrigation units are the Malkerns estate in the Upper Great Usutu basin and the Big Bend, Ubombo Ranches, and Tambuti areas in the Lower Great Usutu basin.

There are about 37,700 ha of potentially irrigable soils in the Lower Great Usutu basin. Previous reports have identified three large tracts of irrigable soils in the Lower Great Usutu basin. These have been identified as the Mapobeni, Big Bend North, and Big Bend South

areas and are located on the west, north, and south sides, respectively, of the existing Big Bend estates. Together, these three areas comprise about 18,000 ha of irrigable land within relatively easy reach of the Lower Great Usutu.

Current annual consumptive uses and demands in the Usutu system total 268 mcm. This total is comprised of a consumptive use of 31 mcm in the upstream portions of the system, water rights for 54 mcm at the Malkerns estate, and a total diversion demand of 183 mcm at Big Bend. The RSA is considering construction of six dams in addition to the three dams that are already operating in the upstream reaches of the Usutu system. From these nine dams, the RSA proposes to reserve 49 mcm per year for Swaziland. With all nine RSA dams in operation and with the annual flow that the RSA proposes to reserve from these dams, the annual surplus at the Big Bend diversion would be 188 mcm.

A total of 29 damsites have been identified in the Usutu system. The advisability of constructing two of these dams is currently under consideration in Swaziland. These are DS 0.1 and DS 0.2 on the Little Usutu river. Of the remaining 27 damsites, seven were selected for this analysis. These seven sites are shown on plate 8 and are presented in table I-11.

Table I-11
Usutu System
Potential Damsites

Site	River	Approximate Location
DS 4.10	Mpuluzi	At RSA border
DS 1.3	Upper Great Usutu	40 km downstream from RSA border
DS 2.2	Ngwempisi	30 km upstream from mouth
DS 3.2	Mkondo	6 km upstream from mouth
DS 4.4	Mhlatuzane	5 km upstream from mouth
DS 4.5	Mhlatuze	10 km upstream from mouth
DS 4.6	Mzimphofu	18 km upstream from mouth

In addition to these damsites, another damsite, DS 1.8 located on the Lower Great Usutu river about 20 km upstream from Siphofaneni, was examined as a potential diversion. Storage was not considered at this site because it would entail significant social and economic disruptions; these disruptions would result from relocations of homes, roads, railroads, and power facilities and from the inundation of prime irrigated land.

DS 4.10 would be located on the Mpuluzi river at the RSA border. This dam could be developed as a joint effort between Swaziland and the RSA. Analysis indicates that a dam at this site with a storage capacity of 140 mcm would be capable of providing an additional 77 mcm annually for irrigation purposes if the proposed RSA dam is not constructed upstream.

DS 4.4, DS 4.5, and DS 4.6 are all on small tributary rivers. The amount of water available for irrigation on these rivers would not be sufficient to develop independent irrigation projects, even with storage at these damsites. The maximum potential lands that could be irrigated from these three damsites, using tributary flows, would range from 600 ha for DS 4.6 to about 1,000 ha for DS 4.4. These damsites do show some potential as offstream storage sites for diversions from the Lower Great Usutu river. In order to be effective for offstream storage, these sites must be capable of storing large quantities of water during the wet season for irrigation use during the dry season. DS 4.4 and DS 4.6 have sufficiently large site capacities to serve as offstream storage sites. This would increase the yield potential of the stream; however, the increase would not be substantial without an extremely large and costly diversion canal. Also, all gravity flows routed through these offstream reservoirs have to enter the reservoir at the maximum pool elevation and be discharged from the outlet works at a considerably lower elevation. This would reduce the opportunities for gravity distribution. If this results in the requirement for pumping

at some downstream location in the irrigation system, the attractiveness of offstream storage would be diminished. A detailed evaluation, beyond the scope of this study, is required to determine if the benefits of offstream storage are greater than the costs and losses.

An analysis was conducted to determine the impact of the construction and operation of DS 0.1 and DS 0.2 on downstream irrigation demands. As presently envisioned, very little consumptive use would occur at these dams. These two dams would be capable of storing about 74 mcm. With this amount of storage, an additional 100 mcm per year could be made available for use in the Lower Great Usutu basin. These dams, therefore, could provide sufficient water to irrigate an additional 6,700 ha, or nearly 40 percent of the combined Mapobeni, Big Bend North, and Big Bend South areas.

Construction of DS 0.1 and DS 0.2, combined with the proposed RSA reserve from the Upper Great Usutu basin and the diversion of existing surplus water in the Lower Usutu basin, would meet about 90 percent of the total potential demands for the combined Mapobeni, Big Bend North, and Big Bend South areas. Variations of this concept have been examined in depth in previous reports, the most recent in early 1980.

The study of the Mapobeni irrigation project is in a relatively advanced stage of planning. This study examined irrigation plans which would provide additional irrigation potential.

Two potential plans have been identified in the Usutu system. The first plan would include the construction of DS 1.3 on the Upper Great Usutu river to provide the water required to complete the Mapobeni irrigation scheme and to irrigate additional lands in the Lower Great Usutu basin. The second plan would include the construction of DS 2.2 on the Ngwempisi river and DS 3.2 on the Mkondo river. These two dams would provide water for a transbasin diversion to irrigate Lowveld

region lands in the Ngwavuma and Pongola basins to the south of the Usutu system.

Under the first plan, the additional flows available from DS 1.3 would be passed through the dam and would flow downstream to DS 1.8. At DS 1.8, these flows would be diverted into a canal on the left (north) bank of the Lower Great Usutu river. DS 1.3 would be constructed to a height of about 80 meters and would have a storage capacity of about 89 mcm. Approximately 6,600 ha of additional lands on the left bank could be irrigated from DS 1.8. The canal would be approximately 81 km in length and would have a capacity of about 6 cms. An economic summary of this plan is shown in table I-12.

This plan would result in the creation of about 3,300 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 6,600 off-farms jobs. About 130 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide for about 2,600 homesteads with an annual income of E3,900. About 25 percent of the land that would be irrigated under this plan is SNL.

Nearly 20,000 ha in the basin have been identified as irrigable in addition to the 18,000 ha in the Mapobeni, Big Bend North, and Big Bend South areas. Realistically, however, the 6,600 ha to be irrigated under this plan may approach the limits of additional land capability in the basin. Detailed soil surveys are required to determine the actual additional amount of land that can be irrigated in the basin.

Detailed future studies should be conducted to more accurately determine the irrigation potential of DS 1.3. Detailed studies should also be conducted to determine the need for offstream storage in the potential Mapobeni irrigation scheme. The economic feasibility of this plan may be improved during detailed planning studies with an analysis

Table I-12
Usutu System
Economic Summary
Additional Irrigation in Lower Great Usutu Basin
(After Completion of Mapobeni Irrigation Scheme)

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Dam			40,000,000
Diversion			350,000
Main Delivery System	81 km	169,415	13,723,000
Distribution System	6,600 ha	719	4,745,000
Land Preparation	6,600 ha	588	3,881,000
General Drainage	6,600 ha	210	1,386,000
Field Tile Drainage	900 ha	1,131	1,018,000
Total Construction Costs			65,103,000
Interest During Construction			10,416,000
Annual Operation and Maintenance			1,852,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	6,600 ha	1,569	10,355,000
Annual Net Revenues without Irrigation	132 homesteads	30	4,000
Productivity Loss	332 ha	235	78,000
Net Irrigation Benefits			10,273,000

INTERNAL RATE OF RETURN (50 YEARS), PERCENT	11

of abstraction rates versus streamflow record lengths, as outlined in the planning assumptions portion of this section.

Under the second plan, DS 2.2 and DS 3.2 would have a combined storage capacity of 764 mcm. This would provide about 120 mcm annually for irrigation. Combined with the 43 mcm which the RSA proposes to reserve for Swaziland from its proposed reservoirs on the Ngwempisi and Mkondo rivers, this plan would be sufficient to irrigate an additional 10,900 ha in the Ngwavuma and Pongola basins. DS 2.2 would be constructed to a height of about 90 meters and would have a storage capacity of 382 mcm. DS 3.2 would be about 60 meters high and would also have a storage capacity of about 382 mcm.

DS 2.2 would be linked by a 23-km-long canal to a diversion located at DS 3.2. The canal from the diversion at DS 3.2 would be about 300 km in length and would have a capacity ranging from 3 to 15 cms. An economic summary of this plan is shown on table I-13.

Implementation of this plan would not preclude the development of DS V on the Ngwavuma river. These two plans may even be combined for efficiency purposes. Detailed operation studies would have to be conducted, however, to determine the advisability of combining these two plans.

This plan would result in the creation of about 5,500 on-farm jobs. At a two-to-one ratio, this would create the opportunity for an additional 11,000 off-farm jobs. About 120 existing homesteads would be resettled from the potential project lands. Assuming each potential homestead is allocated 2.5 ha to farm, this plan would provide about 4,400 homesteads with an annual income of E3,900. About 25 percent of the land that would be irrigated under this plan is SNL.

Table I-13
Usutu System
Economic Summary
Additional Irrigation in the Ngwavuma and Pongola Basins

COSTS

Item	Unit	Unit Cost (Emalangeni)	Total Cost (Emalangeni)
Dams			64,330,000
Diversion			350,000
Main Delivery System	300 km	varies	50,940,000
Distribution System	10,900 ha	719	7,837,000
Land Preparation	10,900 ha	588	6,409,000
General Drainage	10,900 ha	210	2,289,000
Field Tile Drainage	2,377 ha	1,131	2,688,000
Total Construction Costs			134,843,000
Interest During Construction			25,131,000
Annual Operation and Maintenance			3,757,000

BENEFITS

Item	Unit	Unit Value (Emalangeni)	Total (Emalangeni)
Annual Net Revenues with Irrigation	10,900 ha	1,569	17,102,000
Annual Net Revenues without Irrigation	119 homesteads	30	4,000
Productivity Loss	2,671 ha	235	628,000
Net Irrigation Benefits			16,470,000

INTERNAL RATE OF RETURN (50 YEARS), PERCENT 7

DS 2.2, would periodically inundate the western edge of the proposed Ntungulu National Landscape area. This area was proposed for protection because of its scenic qualities and these qualities could be affected by construction of the dam and reservoir. The significance of these effects, both positive and negative, should be examined during any future studies of either of these alternatives.

The best irrigable lands are located in the Ngwavuma and Pongola basins. This plan could be expanded by diverting all flows of the Ngwempisi river at DS 2.2 and the Mkondo river at DS 3.2. These flows could be made up from DS 1.3 by reducing the amount of additional land to be irrigated in the Lower Great Usutu basin under the first plan. This would increase potential irrigation in the Ngwavuma and Pongola basins by 3,600 ha, for a total, including irrigation from DS 2.2 and DS 3.2 and from DS V on the Ngwavuma river, of 16,900 ha.

Detailed future studies of the Usutu system should be conducted to more accurately determine the irrigation potential of DS 2.2 and DS 3.2. The economic feasibility of this plan may be improved with a detailed analysis of abstraction rates versus streamflow record. Canal costs may be reduced by using siphons and tunnels to reduce the canal length; however, a detailed trade-off analysis of canal-length cost versus siphon and tunnel costs should be performed.

SUMMARY OF PRELIMINARY PLAN FORMULATION

Table I-14 summarizes the potential plans identified in the previous paragraphs. The "Total" column includes the Lomati with storage plan, the Mbuluzi plan, the Ngwavuma DS V plan, and both Usutu system plans.

Table I-14
Summary
Preliminary Plan Formulation

Item	Lomati		Mbuluzi	Ngwavuma	Usutu		
	No Storage	With Storage	(Mnjoli)	DS V	DS 1.3	DS 2.2 & DS 3.2	Total[1]
Irrigated Land (1,000 ha)	3,600	14,200	5,000	2,400	6,600	10,900	39,100
Total Construction Cost (E1,000)	10,121	61,949	25,149	16,443	65,103	157,070	325,714
Interest During Construction (E1,000)	1,619	9,912	4,023	2,631	10,416	25,131	52,113
Annual Operation and Maintenance (E1,000)	818	3,307	1,181	591	1,852	3,757	10,688
Net Irrigation Benefits (E1,000)	4,796	18,645	7,831	3,762	10,273	16,470	56,981
Internal Rate of Return - 50 yrs. (percent)	33	21	23	17	11	7	12
Numbers of Jobs Created:							
On-Farm	1,800	7,000	2,500	1,200	3,300	5,500	19,500
Off-Farm	3,600	14,000	5,000	2,400	6,600	11,000	39,000
Number of Homesteads Resettled from Project Lands	300	1,400	500	130	130	120	2,280
Number of Project Homesteads Created	1,400	5,700	2,000	1,000	2,600	4,400	15,700

1/ Includes Lomati with storage, Mbuluzi, Ngwavuma, and both Usutu plans

Canal costs represent a significant portion of the total costs for the Lomati with storage plan, the Mbuluzi plan, and the Usutu DS 2.2 and DS 3.2 plans. A detailed trade-off analysis should be performed to determine potential canal cost reductions through the use of siphons and tunnels to reduce canal length.

The economic feasibility of those plans with storage may be improved during detailed planning with analysis of abstractions versus streamflow record length, as outlined in the planning assumptions portion of this section.

The two Usutu system plans are interrelated with the RSA development plans. For purposes of formulating the two Usutu system plans, it was assumed that the RSA would abstract as much water as it practicably could from its existing and proposed dams upstream from Swaziland. These maximum practicable abstractions are more than twice as much as the RSA estimated needs, as outlined in the latest RSA development plan. Both Usutu system plans, therefore, represent conservative estimates of potential additional irrigation from the Usutu river system, and the actual potential, if the RSA abstracts only its estimated needs from existing and proposed dams, may be much greater than indicated by the two Usutu system plans presented herein. Detailed planning for the Usutu system should be closely coordinated with the RSA development plan.

PART II

SUPPLY-DEMAND ANALYSIS

PART II

SUPPLY-DEMAND ANALYSIS

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INTRODUCTION

Contemporary engineering judgment indicates that the current water demands equal and in some cases exceed, to some degree, the supplies of water currently available in most rivers within Swaziland. This situation has arisen because of considerable irrigation development within Swaziland and because of abstractions by the Republic of South Africa (RSA) for water resources developments upstream from Swaziland.

The purpose of this Supply-Demand Analysis is to show the quantities of water available within Swaziland and the demands that could be met without constructing additional storage in Swaziland for two conditions. These conditions are (1) if there are no further water resources developments in the RSA and (2) if the proposed RSA water resources developments upstream from Swaziland, shown on plate 9, are implemented.

MONTHLY VARIATIONS

The yield obtainable from a river cannot be determined from a study of annual runoff values. The effects of reservoir storage and abstractions must take into account not only variations in annual flows but also in seasonal flows and variations in demand throughout the year. The division of annual flows into monthly volumes is satisfactory for water supply studies of this scope. Yields obtainable directly from riverflows are not as accurately determined using monthly volumes. If the major portion of the monthly volume occurs over several days, only a small portion of the monthly volume would be available without some

storage. The critical period, however, occurs during the low-flow season, when the daily flows should be quite consistent. Use of monthly volumes even in direct river diversions without storage should, therefore, provide a satisfactory determination of the obtainable yields for studies of this scope. This may not be true for small watersheds or basins because of the intermittent nature of the streamflow. This does not affect this analysis because yield determinations are made only at major demand points that are located on major rivers. Seasonal variations are different in each river basin as well as at locations within each basins; therefore, the analysis must be based on recorded data. In this analysis, the recorded volumes for each month of record are used to account for both annual and seasonal variations in flow. All available records were used in this analysis. The number of years of record is different for each river and is shown in table II-1.

Table II-1
Length of Record

River	Record Length (years)
Lomati	24
Komati	70
Mbuluzi	20
Great Usutu	25 and 26
Ngwavuma	19

Monthly demand variations are represented by the average monthly demand for the period of record when demand data were available. Where monthly records were not available, the annual demand was divided into monthly demands based on the average monthly distribution of irrigation demands within the country. Monthly demands as a percentage of annual demands are shown in table II-2.

Table II-2
Monthly Distribution of Demands

Month	Demand in Percent	
	Middleveld Region	Lowveld Region
January	18.4	16.3
February	8.4	10.4
March	5.4	6.7
April	3.0	3.0
May	3.0	4.0
June	1.4	3.7
July	7.8	4.9
August	8.1	5.9
September	4.3	5.6
October	9.2	10.2
November	9.7	11.8
December	21.3	17.5
Total Annual Demand	100.0	100.0

DEMAND LOCATIONS

The scope of this analysis did not allow the development of a complete simulation model for each basin. A separate analysis was required, therefore, for each demand location. Existing demand locations were reviewed with respect to the total annual volumes required relative to the mean annual flows at each demand location; this was done to minimize the number of demand locations for analysis. Where demands were small compared to the volumes available, they were consolidated at a downstream location or were added to a major downstream demand. The flow reliability was calculated at the following diversions--Ngonini, Swaziland Irrigation Scheme (SIS), Simunye, Ngomane, Malkerns, Big Bend, and Nsoko--and at the mouths of major tributaries.

FLOW RELIABILITY

Flow reliability was determined at each demand location. It is represented as an average annual volume in million cubic meters (mcm), in terms of a shortage index, and as the number of years per 100 years that a shortage is expected to occur.

The RSA and Swaziland currently consider a stream yield reliable if no more than 20 shortage years are expected during a 100-year period. This type of measurement accounts only for the number of shortages and not for the severity of each shortage. If it can be assumed that the severity of shortages is distributed similarly in all basins and at all points within each basin, the shortage recurrence would be a consistent measure of both the severity and the frequency of shortages. Analysis of the data indicates, however, that this is not the case. The relative number of large, costly shortages to small, insignificant shortages varied considerably. Because the shortage recurrence measurement weighs each shortage the same regardless of its severity, a given shortage recurrence may represent a disastrous situation in one case and a tolerable one in another.

The shortage index measures the severity as well as the recurrence of shortages. Large shortages are far more serious in their economic impact than are small shortages, and the economic impact of a shortage is assumed to vary with some power (greater than one) of the percent of shortage. The shortage index used in this analysis is a function of the square of the quotient of the shortage divided by the demand. This implies that shortages of 40 percent are four times as serious as shortages of 20 percent and that shortages of 60 percent are nine times as severe as shortages of 20 percent. Use of this relationship permits the development of a single index convenient for planning purposes.

The tolerable shortage adopted for this analysis is represented by a shortage index of 0.25. It is defined as the sum of the squares of all shortages expected during a 100-year period when each annual shortage is expressed as a fraction of the annual demand. This would permit, for example, 25 shortages of 10 percent each during 100 years, about 6 shortages of 20 percent each, or 1 shortage of 50 percent if all shortages were of the same severity. A shortage index of 0.25 could also result from 12 shortages of 5 percent each, 5 shortages of 10 percent each, 2 shortages of 20 percent each, and 1 shortage of 30 percent in 100 years ($12 \times (0.05)^2 + 5 \times (0.1)^2 + 2 \times (0.2)^2 + (0.3)^2 = 0.25$). A more detailed discussion of the shortage index and its use is included in the Hydrology Section of Part IV.

EFFECTS OF STREAMFLOW RECORD LENGTH ON SUPPLY-DEMAND ANALYSIS

As shown in the Hydrology Section of Part IV, streamflow yield analysis is highly dependent on streamflow record length for without storage conditions. Except for the Komati river, the record lengths for streams in Swaziland are extremely short, ranging from 19 to 26 years.

A sensitivity analysis of streamflow record length versus streamflow yield was conducted on the Komati river. It was determined that the use of short record lengths could result in a significant overstatement of potential streamflow irrigation yield for without storage conditions. Detailed analysis of streamflow records versus streamflow yield is required during the next stage of study, as outlined in Part III, Detailed Planning.

REPUBLIC OF SOUTH AFRICA ABSTRACTIONS

The RSA has constructed five major dams on rivers discharging into Swaziland and is proposing the construction of seven additional dams. Surpluses or shortages were determined for demand locations within Swaziland with the 5 existing dams and with all 12 dams. The locations of these dams are shown on plate 9. The storage capacities of the RSA dams were obtained from the RSA report "Possible Future Development in the Republic of South Africa of the Rivers of Common Interest with the Kingdom of Swaziland," 1980.

Abstraction records for the existing dams were available from the RSA. Planned abstractions from the proposed RSA dams were obtained from the RSA development plan named above. The RSA has indicated in the development plan that once the proposed reservoirs are constructed, specified releases from these reservoirs would be reserved for Swaziland.

An analysis of these existing and planned abstractions indicated that in all cases the potential abstractions could be considerably larger. These larger abstraction rates are identified as maximum practicable abstractions. Maximum practicable abstractions are defined as the abstractions that could be made on a uniform monthly basis that would result in a shortage index of 0.25.

EFFECTS OF RSA ABSTRACTIONS ON SUPPLY-DEMAND ANALYSIS

The existing and proposed RSA development affects the Komati, Upper Great Usutu, Ngwempisi, and Mkondo rivers. The supply-demand analysis

for these rivers examined two conditions: existing RSA development and proposed RSA development. Under existing RSA development, the effects on existing Swaziland irrigation were examined assuming the RSA would abstract water from its existing dams at the maximum practicable abstraction rate (shortage index of 0.25). Under proposed RSA development, the effects on existing Swaziland irrigation were examined assuming both planned RSA abstractions and maximum practicable RSA abstractions. Both assumptions include the proposed Swaziland reserve from the RSA. In all cases, the maximum practicable RSA abstraction could be significantly larger than the planned RSA abstraction. The resulting effects on existing Swaziland irrigation, however, would be very similar under either assumption about the RSA abstractions. This occurs because of the monthly distribution of streamflow and because of the fact that the various existing Swaziland irrigation diversions abstract water on a run-of-river basis.

Under either planned or maximum practicable RSA abstractions, the RSA would be using nearly all of the streamflow available during the dry months of the year while releasing, or spilling, large volumes of water during the wet months. These spills, on a total annual basis, would be considerably larger for the planned RSA abstractions than they would be for the maximum practicable RSA abstractions. Total annual flow at the existing Swaziland irrigation diversions would, therefore, be considerably different for these two conditions on a monthly basis; however, almost of all this difference would occur during the wet months of the year. Flows during the dry months would be nearly the same. Because there is little or no storage at the existing Swaziland irrigation diversions, there is no potential to store water during the wet months for use during the dry months. The difference in flows between planned and maximum practicable RSA abstractions is, therefore, simply passed through these existing diversions. Without storage in Swaziland, it makes very little difference whether the RSA abstracts water at the planned or at the maximum practicable rate.

This analysis has significant implications for irrigation in Swaziland. The maximum practicable RSA abstractions could be considered to be the optimum operating plan for the existing and proposed RSA dams. If the RSA uses only its planned abstractions, the additional abstractions available under the maximum practicable abstraction rates could be reserved for Swaziland. These additional abstractions (maximum practicable RSA abstractions minus planned RSA abstractions) represent very large amounts of water in each affected basin, as shown in the supply-demand tables. This potential should be considered during any negotiations between the two countries.

SUMMARY OF RESULTS

The results of the supply-demand analysis are discussed separately for each basin and are summarized in a series of tables at the end of this discussion.

LOMATI

The supply-demand summary of the Lomati basin indicates that the current annual demand of 13 mcm can be met consistently without construction of storage facilities. Moreover, the demand at the Ngonini diversion could be increased to 47 mcm per year with an acceptable shortage index of 0.25. This implies a current annual surplus of 34 mcm at the Ngonini diversion.

KOMATI

The supply-demand summary of the Komati basin shows that the RSA abstractions from its existing reservoirs could be increased from 86 to

175 mcm per year without exceeding a shortage index of 0.25. With these increased abstractions, the shortage index at the SIS weir would be 1.84. The SIS demands would have to be reduced by 96 mcm per year (56 percent) to attain a shortage index of 0.25. A shortage index of 0.25 could also be maintained if the RSA limited its abstractions to 79 mcm. Because so many of the shortages are fairly small and occur only during 1 month of the year, they are not severe and do not add a large value to the shortage index. Even the acceptable shortage index of 0.25 represents nearly 30 years of deficit per 100 years. The shortages that would have occurred during the 70-year period of record under these conditions are listed in table II-3. Table II-3 also presents the summation of shortage percentages and the shortage index. The consequences of these shortages are not expected to be great because of the low magnitude of the shortages indicated by the low shortage index of 0.25. It is not unusual to have a low and acceptable shortage index along with a significant number of shortage years when demands are made on run-of-river flows.

Hooggenoeg dam would be constructed on the Komati river under the current RSA development plan. With the two existing dams and the proposed Hooggenoeg dam in operation, the RSA proposes to abstract 299 mcm per year for use in the RSA and to reserve 65 mcm per year for Swaziland. Under these conditions, the shortage at the SIS weir would be about 92 mcm annually compared to 96 mcm annually under current maximum RSA abstraction conditions. If the reserve of 65 mcm per year were not available, the shortage index at the SIS weir would be 11.4 with an average shortage of 157 mcm expected every year.

With the two existing dams and Hooggenoeg dam in operation, maximum practicable RSA abstractions would be 343 mcm per year. This would present unallocated potential abstractions of 44 mcm per year. If these unallocated abstractions were made available to the SIS, the shortage

Table II-3
Shortage Record at Swaziland Irrigation Scheme
RSA Abstractions = 175 mcm/year
Upstream Consumption = 1 mcm/year
Eastern Border Demand = 38 mcm/year
Reduced Swaziland Irrigation Scheme Demand = 74 mcm/year
Shortage Index = 0.22
Shortage (mcm)

Month	Monthly Demand (mcm)	Water Year 1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946
Oct	6	0	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	6
Nov	7	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	7
Dec	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Jan	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
Mar	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Jun	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Jul	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Aug	7	0	1	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	6	0
Sep	7	2	3	0	0	3	3	3	0	1	0	0	0	0	0	1	1	0	0	7	3
Total	74	4	4	3	0	3	5	5	2	1	1	0	0	0	0	1	7	0	0	16	20
Shortage Percent Squared		.0029	.0029	.0019		.0019	.0046	.0046	.0007	.0002	.0002					.0002	.0089			.0468	.0731

Note: No shortages experienced from 1911 to 1926.

Table II-3 (Cont'd)
Shortage Record at Swaziland Irrigation Scheme
RSA Abstractions = 175 mcm/year
Upstream Consumption = 1 mcm/year
Eastern Border Demand = 38 mcm/year
Reduced Swaziland Irrigation Scheme Demand = 74 mcm/year
Shortage Index = 0.22
Shortage (mcm)

Month	Monthly Demand (mcm)	Water Year 1947	1948	1949	1950	1951	1952	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Oct	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mar	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sep	7	0	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	1	1
Total	74	5	0	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	1	1
Shortage Percent Squared		.0046					.0007	.0002		.0002									.0002	.0002

Sum of all Squares = .155

Shortage Index = $\frac{100}{70}$ x 0.155 = 0.22

Note: No shortages experienced from 1953 to 1963.

at the SIS weir would be 48 mcm per year. If the RSA uses the unallocated abstractions, the shortage at the SIS weir would be 93 mcm per year.

With the proposed reserve of 65 mcm per year, the current shortages at the SIS weir, with maximum RSA abstractions, would not greatly change. In fact, the current shortages at the SIS weir would be slightly reduced. Three options are available to mitigate the SIS shortages. The first option would be for the RSA to reduce its abstractions from its existing and proposed reservoirs, thereby sharing the shortages equally with Swaziland. The second option would be for the RSA to increase the proposed reserve for Swaziland up to the difference between the maximum practicable abstractions and the planned abstractions, or about 44 mcm per year. This would bring the total proposed Swaziland reserve to 109 mcm per year. The third option would be to provide storage in Swaziland at Damsite (DS) 6.5. In order to make up the shortages at the SIS weir, DS 6.5 would need to be constructed with a storage capacity of about 75 mcm at a total cost of about E15 million.

MBULUZI

The supply-demand summary of the Mbuluzi basin indicates that with the existing Mnjoli dam and reservoir, the Mozambique border demands, all existing irrigation demands, and all planned irrigation demands for the Ngomane diversion can be met practically all the time. It also indicates that the planned irrigation demands for the Ngomane diversion could be increased by nearly 75 percent without reducing the reliability of existing border and irrigation demands. This is only true if diversion rates are 2.1 hectare-meters per hectare. Higher or lower rates would require a linear adjustment in the reliable demand. The supply-demand summary did not include the 13 mcm reserve for Mbabane in the upper reaches of the Black Mbuluzi river.

Because much of the demands downstream from Mnjoli dam are met by the return flows from the SIS, and thus the Komati river, the potential

increase in irrigation from Mnjoli dam is dependent upon the SIS demands that are met by the Komati river. The above analysis is based on return flows from the full SIS demands of 170 mcm per year. If, however, the SIS demands are not fully met, more of the downstream demand would have to be met from Mnjoli releases and the potential increase in demand from Mnjoli dam would be reduced. If the SIS demands are reduced by 50 to 55 percent as shown in the Komati basin supply-demand summary, then the irrigation demand from Mnjoli dam could be increased by only about 55 percent over the planned Ngomane diversion irrigation demand.

LITTLE USUTU

Total current annual consumption in the Little Usutu basin is about 3 mcm. The basin produces 445 mcm annually of which 187 mcm is available for irrigation use at the mouth with a shortage index of 0.25.

UPPER GREAT USUTU

The major water user in the Upper Great Usutu basin is Malkerns estate. The supply-demand summary indicates that the annual RSA abstractions from Westoe dam could be increased from the current 40 mcm up to 56 mcm without exceeding a shortage index of 0.25. Even with this increased abstraction by the RSA, there would still be no shortage at the Malkerns diversion. There would be a surplus of 88 mcm per year.

The RSA plans to construct Busby dam on the Mpuluzi river. With Westoe and Busby dams in operation, the RSA plans to abstract a total of 63 mcm per year while reserving 6 mcm per year for Swaziland. Under these conditions, the surplus at the Malkerns diversion would be 76 mcm per year, including the proposed RSA reserve for Swaziland.

Maximum practicable RSA abstractions would be 138 mcm per year and the unallocated potential abstractions would, therefore, be 75 mcm per

year. If these unallocated abstractions were made available, the surplus at the Malkerns diversion could be about 151 mcm per year. If the RSA uses these unallocated potential abstractions, the surplus at the Malkerns diversion would be 68 mcm per year. With the proposed RSA reserve for Swaziland, this surplus would be 74 mcm per year.

NGWEMPISI

The RSA average annual abstractions from Jericho and Morgenstond dams amount to 37 mcm. These abstractions could be increased to 89 mcm per year without exceeding a shortage index of 0.25. With these increased abstractions, there would still be a surplus of 91 mcm per year in the Ngwempisi basin.

The RSA plans to construct Merriekloof, Watervaldrift, and Ishlelo dams in the Ngwempisi basin. With the two existing and the three proposed dams in operation, the RSA plans to abstract 125 mcm per year for use in the RSA and to reserve 15 mcm per year for Swaziland. Under these conditions, the surplus available at the mouth of the Ngwempisi river would be 39 mcm per year.

Maximum practicable RSA abstractions for the existing and proposed dams would be 232 mcm per year. The unallocated potential abstractions would, therefore, be 107 mcm per year. If these unallocated abstractions were made available to Swaziland, the surplus at the mouth of the Ngwempisi river would be 146 mcm per year. If the RSA uses these unallocated abstractions, this surplus would be 38 mcm per year.

MKONDO

The supply-demand summary of the Mkondo basin indicates that there is a surplus of 129 mcm per year at the mouth. As with all tributaries of the Great Usutu river, this is not truly a surplus because much of

it may be allocated to downstream users. It is, however, surplus to the demands within the basin and represents the contribution that the Mkondo river makes toward meeting downstream demands.

The RSA plans to construct Heyshope and DeKraalen dams in the Mkondo basin to abstract a total of 167 mcm per year while providing a reserve to Swaziland of 28 mcm per year. Under these conditions, the surplus at the mouth of the Mkondo river in Swaziland would be 57 mcm per year.

Maximum practicable RSA abstractions from these two proposed RSA dams would be 350 mcm per year. The unallocated potential abstractions would, therefore, be 183 mcm per year. If these unallocated abstractions were made available at the mouth of the Mkondo river, the surplus in Swaziland would be 240 mcm per year. If the RSA uses these unallocated abstractions, this surplus in Swaziland would be 51 mcm per year.

GREAT USUTU

The largest water user in the Great Usutu basin is a large area served by the Big Bend diversion. Current demands for Big Bend estates are estimated to total about 183 mcm per year. Current consumptive use upstream from Big Bend estates within Swaziland is approximately 85 mcm per year. The RSA is currently abstracting 77 mcm per year from its three existing reservoirs. It could increase these abstractions to 145 mcm per year without exceeding a shortage index of 0.25. If the RSA increases its abstractions to 145 mcm per year and if the current upstream consumptive use within Swaziland remains to be 85 mcm per year, no shortages would be expected during a period of 100 years at the Big Bend estates. Under these conditions, the demand at Big Bend estates could be increased to 559 mcm per year without exceeding a shortage index of 0.25. This implies a surplus of 376 mcm per year under these conditions. Table II-4 lists the shortages that would have been

Table II-4
Shortage Record at Big Bend Estates
RSA Abstractions = 145 mcm/year
Upstream Consumption = 85 mcm/year
Big Bend Demand = 559 mcm/year
Shortage Index = 0.24
Shortage (mcm)

Month	Monthly Demand (mcm)	Water Year 1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Oct	57	33	0	0	0	0	11	6	0	0	0	0	0	22	19	25	38	0	0	0	13	0	19	0	0	18
Nov	66	0	0	0	0	0	0	0	0	0	0	0	0	5	33	0	0	0	0	0	0	0	0	0	0	14
Dec	98	0	0	0	0	0	0	0	0	0	0	1	0	30	0	0	0	0	29	0	0	0	0	47	0	0
Jan	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0
Mar	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jun	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul	27	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	33	0	0	0	0	0	0	0	0	2	0	13	5	8	0	0	0	0	0	0	0	0	0	0	0	0
Sep	32	0	0	0	0	0	0	0	0	2	0	15	0	9	0	2	0	0	0	0	0	0	0	0	0	0
Total	559	33	0	0	0	0	11	6	0	4	0	30	5	74	52	27	51	0	29	0	13	0	19	47	0	32
Shortage Percent Squared		.0035					.0004	.0001		.0001		.0029	.0001	.0175	.0087	.0023	.0083		.0027		.0005		.0012	.0071		.0033

Sum of All Squares = .0587

Shortage Index = $\frac{100}{25}$ x .0587 = 0.24

experienced at Big Bend estates during the 26 years of record if the RSA were abstracting 145 mcm per year, if upstream consumption in Swaziland were 85 mcm per year, and if the demands at Big Bend estates were increased to 559 mcm per year.

The RSA plans to construct Busby, Watervaldrift, Merriekloof, Ishlelo, Heyshope, and DeKraalen dams on the upstream tributary rivers. With the three existing dams and these six proposed dams in operation, the RSA plans to abstract 355 mcm per year while reserving 49 mcm per year for Swaziland. Under these conditions, the surplus at the Big Bend diversion would be 197 mcm per year.

Maximum practicable RSA abstractions would be 720 mcm per year from the existing and proposed RSA dams. The unallocated potential abstractions would, therefore, be 365 mcm per year. If these unallocated abstractions were made available at the Big Bend diversion, the total surplus would be 562 mcm per year. If the RSA uses these unallocated abstractions, this surplus at the Big Bend diversion would be 322 mcm per year.

NGWAVUMA

The supply-demand summary of the Ngwavuma basin indicates that although the demands of 39 mcm can probably be met in all but 22 years out of 100, the magnitudes of the shortages are likely to be very significant as indicated by the large shortage index of 1.8. If the annual demand were reduced by 14 mcm to 25 mcm, it could be met with an acceptable shortage index of 0.25. This represents a sizable shortage--approximately 40 percent of the current demand.

SUPPLY-DEMAND SUMMARY
LOMATI

Mean Annual Flows

Western border: 78 mcm
Gage station 11: 174 mcm
Eastern border: 213 mcm

Flow Reliability At The Ngonini Diversion (Gage Station 11)

Current demand: 13 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0
Demand that could be met with shortage index of 0.25: 47 mcm/year
Surplus: 34 mcm/year

SUPPLY-DEMAND SUMMARY
KOMATI
Existing RSA Development

Existing RSA Development

Vygeboom: 79 mcm capacity
Nooitgedacht: 79 mcm capacity

Current RSA Abstractions

86 mcm/year

RSA Abstractions With Shortage Index of 0.25

175 mcm/year

Mean Annual Flows With RSA Abstractions (Shortage Index of 0.25)

Western border: 485 mcm
SIS weir: 705 mcm
Eastern border: 765 mcm

Flow Reliability At The SIS Weir With RSA Abstractions (Shortage Index of 0.25)

Upstream consumptive use: 1 mcm/year
SIS demand: 170 mcm/year
Eastern border demand: 38 mcm/year
Number of years of shortage per 100 years: 90
Shortage index: 1.84
SIS demand that could be met with shortage index of 0.25: 74 mcm/year
Shortage at the SIS weir: 96 mcm/year

SUPPLY-DEMAND SUMMARY
KOMATI
Proposed RSA Development

Existing RSA Development

Vygeboom: 79 mcm capacity
Nooitgedacht: 79 mcm capacity

Potential RSA Development

Hooggenoeg: 484 mcm capacity (estimated completion by 1996)

Current Plus Planned RSA Abstractions

299 mcm/year

Proposed Reserve For Swaziland

65 mcm/year

Mean Annual Flows With Planned RSA Abstractions

Western border: 361 mcm
SIS weir: 581 mcm
Eastern border: 641 mcm

Flow Reliability At The SIS Weir With Planned RSA Abstractions

Upstream consumptive use: 1 mcm/year
SIS demand: 170 mcm/year
Eastern border demand: 38 mcm/year
Number of years of shortage per 100 years: 100
Shortage index: 11.4
SIS demand that could be met with shortage index of 0.25: 13 mcm/year
Shortage at the SIS weir: 157 mcm/year
Shortage at the SIS weir with Swaziland reserve from RSA: 92 mcm/year

Supply-Demand With Maximum Practicable RSA Abstractions

Maximum practicable RSA abstractions: 343 mcm/year
Unallocated potential abstractions: 44 mcm/year (343-299)
Shortage at the SIS weir with unallocated potential abstractions:
48 mcm/year (approx.)

SUPPLY-DEMAND SUMMARY
MBULUZI

Mean Annual Flows

Black Mbuluzi
- Gage station 3: 224 mcm
- Mnjoli dam: 240 mcm
- Confluence with White Mbuluzi: 310 mcm

White Mbuluzi
- Gage station 10: 22 mcm
- Confluence with Black Mbuluzi: 31 mcm

Mbuluzi
- Confluence: 341 mcm
- Mozambique border: 420 mcm1/

Flow Reliability At The Mozambique Border1/

Current demand: 98 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0

Flow Reliability At The Simunye Diversion

Current demand: 118 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0

Flow Reliability At The Ngomane Diversion

Upstream consumptive use: 6 mcm/year
Planned demand: 103 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0
Demand that could be met with no downstream shortages: 179 mcm/year
Surplus: 76 mcm/year
Demand that could be met with SIS return flows of 31 mcm/year: 161 mcm/year
Surplus: 58 mcm/year

1/ Includes SIS return flows (68 mcm/year)

SUPPLY-DEMAND SUMMARY
LITTLE USUTU

Mean Annual Flows

Western border: 45 mcm
Gage station 15: 160 mcm
Gage station 2: 405 mcm
Swaziland Electricity Board diversion: 410 mcm
Mouth: 445 mcm

Flow Reliability At The Mouth

Existing consumptive demand in Little Usutu basin: less than 1 mcm/year
Demand that could be met with shortage index of 0.25: 187 mcm/year
Surplus: 187 mcm/year

SUPPLY-DEMAND SUMMARY
UPPER GREAT USUTU
Existing RSA Development

Existing RSA Development

Westoe: 60 mcm capacity

Current RSA Abstractions

40 mcm/year

RSA Abstractions With Shortage Index of 0.25

56 mcm/year

Mean Annual Flows With RSA Abstractions (Shortage Index of 0.25)

Western border: 224 mcm
Malkerns diversion weir: 389 mcm
Confluence with Lower Great Usutu river: 419 mcm

Flow Reliability At The Malkerns Diversion With RSA Abstractions (Shortage Index of 0.25)

Upstream consumptive use: 4 mcm/year
Malkerns water right: 54 mcm
Number of years of shortage per 100 years: 0
Shortage index: 0
Demand that could be met with shortage index of 0.25: 142 mcm/year
Surplus: 88 mcm/year

SUPPLY-DEMAND SUMMARY
UPPER GREAT USUTU
Proposed RSA Development

Existing RSA Development

Westoe: 60 mcm capacity

Potential RSA Development

Busby: 70 mcm capacity (estimated completion by 1990)

Current Plus Planned RSA Abstractions

63 mcm/year

Proposed Reserve For Swaziland

6 mcm/year

Mean Annual Flows With Planned RSA Abstractions

Western border: 217 mcm
Malkerns weir: 382 mcm
Confluence with Lower Great Usutu river: 412 mcm

Flow Reliability At The Malkerns Weir With Planned RSA Abstractions

Upstream consumptive use: 4 mcm/year
Malkerns water right: 54 mcm/year
Number of years of shortage per 100 years: 14
Shortage index: 0.001
Demand that could be met with shortage index of 0.25: 124 mcm/year
Surplus: 70 mcm/year
Surplus with Swaziland reserve from RSA: 76 mcm/year

Supply-Demand With Maximum Practicable RSA Abstractions

Maximum practicable RSA abstractions: 138 mcm/year
Unallocated potential abstractions: 75 mcm/year (138-63)
Surplus at the Malkerns weir with unallocated potential abstractions: 151 mcm/year (approx.)

SUPPLY-DEMAND SUMMARY
NGWEMPISI
Existing RSA Development

Existing RSA Development

Jericho: 60 mcm capacity
Morgenstond: 114 mcm capacity

Current RSA Abstractions

37 mcm/year

RSA Abstractions With Shortage Index of 0.25

89 mcm/year

Mean Annual Flows With RSA Abstractions (Shortage Index of 0.25)

Western border: 213 mcm/year
Gage station 5: 271 mcm/year
Mouth: 291 mcm/year

Flow Reliability At The Mouth With RSA Abstractions (Shortage Index of 0.25)

Existing consumptive use within basin: 8 mcm/year
Demand that could be met with shortage index of 0.25: 91 mcm/year
Surplus: 91 mcm/year

SUPPLY-DEMAND SUMMARY
NGWEMPISI
Proposed RSA Development

Existing RSA Development

Jericho: 60 mcm capacity
Morgenstond: 114 mcm capacity

Potential RSA Development

Watervaldrift: 170 mcm capacity (estimated completion by 1989)
Merriekloof: 160 mcm capacity (estimated completion by 1990)
Ishlelo: 50 mcm capacity (estimated completion by 1995)

Current Plus Planned RSA Abstractions

125 mcm/year

Proposed Reserve For Swaziland

15 mcm/year

Mean Annual Flows With Planned RSA Abstractions

Western border: 177 mcm/year
Gage station 5: 235 mcm/year
Mouth: 255 mcm/year

Flow Reliability At The Mouth With Planned RSA Abstractions

Existing consumptive use within basin: 8 mcm/year
Demand that could be met with shortage index of 0.25: 24 mcm/year
Surplus: 24 mcm/year
Surplus with Swaziland reserve from RSA: 39 mcm/year

Supply-Demand With Maximum Practicable RSA Abstractions

Maximum practicable RSA abstractions: 232 mcm/year
Unallocated potential abstractions: 107 mcm/year (232-125)
Surplus at the mouth with unallocated potential abstractions: 146 mcm/year (approx.)

SUPPLY-DEMAND SUMMARY
MKONDO
Existing RSA Development

Existing RSA Development

None

Mean Annual Flows

Western border: 405 mcm/year
Gage station 7: 455 mcm/year
Mouth: 458 mcm/year

Flow Reliability At The Mouth

Current consumptive use within basin: 3 mcm/year
Demand that could be met with shortage index of 0.25: 129 mcm/year
Surplus: 129 mcm/year

SUPPLY-DEMAND SUMMARY
MKONDO
Proposed RSA Development

Potential RSA Development

Heyshope: 460 mcm capacity (estimated completion by 1984)
DeKraalen: 28 mcm capacity (estimated completion by 1992)

Planned RSA Abstractions

167 mcm/year

Proposed Reserve For Swaziland

28 mcm/year

Mean Annual Flows With Planned RSA Abstractions

Western border: 238 mcm/year
Gage station 7: 288 mcm/year
Mouth: 291 mcm/year

Flow Reliability At The Mouth With Planned RSA Abstractions

Current consumptive use within basin: 3 mcm/year
Demand that could be met with shortage index of 0.25: 29 mcm/year
Surplus: 29 mcm/year
Surplus with Swaziland reserve from RSA: 57 mcm/year

Supply-Demand With Maximum Practicable RSA Abstractions

Maximum practicable RSA abstractions: 350 mcm/year
Unallocated potential abstractions: 183 mcm/year (350-167)
Surplus at the mouth with unallocated potential abstractions:
240 mcm/year

SUPPLY-DEMAND SUMMARY
GREAT USUTU
Existing RSA Development

Existing RSA Development

Westoe: 60 mcm capacity
Jericho: 60 mcm capacity
Morgenstond: 114 mcm capacity

Current RSA Abstractions

77 mcm/year

RSA Abstractions With Shortage Index of 0.25

145 mcm/year

Mean Annual Flows With RSA Abstractions (Shortage Index of 0.25)

Confluence with upstream tributaries: 1,617 mcm
Gage station 6: 1,658 mcm
Big Bend diversion: 1,721 mcm
Eastern border: 1,759 mcm

Flow Reliability At The Big Bend Diversion With RSA Abstractions (Shortage Index of 0.25)

Current consumptive use upstream: 85 mcm/year
Big Bend demands: 183 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0
Demand that could be met with shortage index of 0.25: 559 mcm/year
Surplus: 376 mcm/year

SUPPLY-DEMAND SUMMARY
GREAT USUTU
Proposed RSA Development

Existing RSA Development

Westoe: 60 mcm capacity
Jericho: 60 mcm capacity
Morgenstond: 114 mcm capacity

Potential RSA Development

Busby: 70 mcm capacity
Watervaldrift: 170 mcm capacity
Merriekloof: 160 mcm capacity
Ishlelo: 50 mcm capacity
Heyshope: 460 mcm capacity
DeKraalen: 280 mcm capacity

Planned RSA Abstractions

355 mcm/year

Proposed Reserve For Swaziland

49 mcm/year

Mean Annual Flows With Planned RSA Abstractions

Confluence with upstream tributaries: 1,407 mcm
Gage station 6: 1,448 mcm
Big Bend diversion: 1,511 mcm
Eastern border: 1,585 mcm

Flow Reliability At The Big Bend Diversion With Planned RSA Abstractions

Current consumptive use upstream: 85 mcm/year
Big Bend demands: 183 mcm/year
Number of years of shortage per 100 years: 0
Shortage index: 0
Demand that could be met with shortage index of 0.25: 331 mcm/year
Surplus: 148 mcm/year
Surplus with Swaziland reserve from RSA: 197 mcm/year

Supply-Demand With Maximum Practicable RSA Abstractions

Maximum practicable RSA abstractions: 720 mcm/year
Unallocated potential abstractions: 365 mcm/year (720-355)
Surplus at the Big Bend diversion with unallocated potential abstractions: 562 mcm/year

SUPPLY-DEMAND SUMMARY
NGWAVUMA

Mean Annual Flows

Nsoko diversion (gage station 8): 94 mcm
Eastern border: 106 mcm

Flow Reliability At The Nsoko Diversion

Current demand: 39 mcm/year
Number of years of shortage per 100 years: 22
Shortage index: 1.8
Demand that could be met with shortage index of 0.25: 25 mcm/year
Shortage: 14 mcm/year

PART III

DETAILED PLANNING

PART III

DETAILED PLANNING

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INTRODUCTION

The detailed planning studies that must be performed in order to implement any of the plans presented in this report are discussed in this section. These detailed planning studies can be divided into two broad categories. The first category, general studies, includes those types of studies for which a broad analysis can be performed and then used in the development of all the different plans presented in this report. This category includes studies that represent a long-term commitment to solving various water-related problems in Swaziland, such as stream gaging programs, ground water analysis, and fish and wildlife inventories. The data development and analyses, however, could also be used in the development of irrigation projects. The second category, project studies, includes the specific tasks which are required to develop the irrigation project plans presented in this report. This category includes such tasks as hydrologic analysis, project design, and soils surveys.

Study costs are presented only for the project studies. A summary of total project study costs is presented at the end of this section.

GENERAL STUDIES

General studies need to be initiated immediately. These studies would be an integral part, not only of the project studies, but also of all water and natural resources planning in Swaziland.

REPUBLIC OF SOUTH AFRICA RESERVOIR DATA

Additional information is required from the Republic of South Africa (RSA) concerning the future operational plans of its existing reservoirs in conjunction with its proposed reservoirs. The operating plan for these reservoirs will be required input to a multiple reservoir computer program that will be developed in the future project studies. This information needs to be collected prior to initiation of any irrigation studies in the Usutu river basin or in the Komati river basin. Studies in either of these basins should be staged in such a manner that this information would be available at the time that the project studies are initiated.

ADDITIONAL GAGING STATIONS

Action should be taken now by the Government of Swaziland (GOS) to organize a gaging station network at or near potential damsites (DS) 4.6, 7.1, 7.2, and 7.3 because these sites are not located near an existing gaging station. This station network would be used to collect representative flow data for comparison with flow data at existing stations, thereby improving the reliability of the estimate at the respective reservoir sites.

DETAILED FISH AND WILDLIFE INVENTORIES

Detailed inventories of the fish and wildlife resources of Swaziland would be a valuable aid to irrigation project planning as well as to all natural resource planning. Wildlife resources have rapidly diminished over the past century. Virtually nothing is known concerning fishery resources in Swaziland. The first step in planning for the protection and enhancement of fish and wildlife resources would be a detailed inventory of these resources and an analysis of habitat requirements and availability.

After determining the important species or wildlife communities, observation over a full year would be desirable to record seasonal vegetational

responses, migrations, and other periodic phenomena. The need for extended studies would depend on the species involved and the conditions surrounding the first year's study. Review and monitoring would require repeated observations at intervals of 2 or 3 years; these observations would focus on key seasons and key species.

SEDIMENT ANALYSIS

A sediment sampling and analysis program should be developed to aid in dam design studies. Sediment sampling should be conducted particularly during times of high flows. All previous sediment studies should be examined. Dam designs in the RSA should be analyzed to determine the sediment design criteria, particularly for dams on rivers that flow through Swaziland.

GROUND WATER ANALYSIS

A systematic ground water testing and sampling program should be developed and used to determine those areas where ground water supplies would be adequate for rural domestic and livestock watering needs and for irrigation needs. This program should include plans for an analysis of the well-flow capacity and the water quality.

A well-flow capacity analysis would be required to determine the potential magnitude of rural domestic or small irrigation water supply projects. Special consideration should be given to determining the amount of water that can be removed without depleting an individual ground water source by exceeding its recharge capacity.

A water quality analysis would be required to determine whether ground water sources are of adequate quality for domestic, livestock, or irrigation needs. Particular attention should be given to finding sources adequate for the domestic water supply needs.

This program should initially concentrate on two types of areas -- the first should be those areas where water-related disease problems, due to polluted surface waters, are most severe. These areas would primarily be located in the Lowveld region. In this respect, the ground water program should be closely coordinated with existing disease and health programs in Swaziland.

The second type should be those areas where a large-scale irrigation scheme is being considered. Ground water sources in these areas may provide opportunities for the development of pilot projects associated with these schemes. In this respect, the program should be closely coordinated with ongoing irrigation project planning in Swaziland.

SOCIAL SURVEYS

Numerous surveys of rural Swazis have been made. Irrigation project planning would be greatly enhanced through the use of information that could be received by the implementation of a survey of farmers at the Vuvulane Irrigation Scheme. This survey should focus on the farmers' satisfaction or dissatisfaction with the project layout, facilities, housing, management, and operations. This survey could be used in the development of the plans presented in this report.

PRODUCTION AND MARKETING STUDIES

Production and marketing studies should be initiated concurrently with detailed planning for irrigation projects. These studies would allow for the development of costs and benefits associated with irrigation project cropping.

These studies should include the analysis of potential crop types-versus-irrigation area factors such as soils types, precipitation and water application requirements, growing season length, and yield. Where additional

crop research needs are identified, it is anticipated that arrangements could be made with the agriculture school or existing irrigation schemes to carry out this research during planning and design of the project.

The identification of all production input costs associated with different types of crops should be included in these studies.

Detailed marketing studies should be conducted to determine the marketing potential of different types of crops both inside and outside of Swaziland. The marketing studies should identify the potential effects of increased agricultural production on the existing marketing system. In conjunction with this, the potential need for increased agricultural processing facilities should be identified.

PROJECT STUDIES

The total project implementation process would include five phases. This framework study is the first phase. The second phase would include preliminary design and evaluation of each of the plans identified in this framework study. The major emphasis of the second phase would be placed on screening the relative merits of these potential plans to provide a basis for the detailed design, or third phase of the study. The third phase would provide detailed designs and specifications for those projects which were selected during the second phase. The fourth phase would be construction of the project(s), and the fifth phase would be operation of the project(s).

This section of the report will focus on and outline the study tasks required for the second phase of the study. Subsequent phases are not

addressed in detail; however, if feasible projects are found in the Lomati, Mbuluzi, Usutu, and Ngwavuma basins, it is estimated that the minimum time required to bring all projects into operation would be approximately 8 to 10 years.

This framework study presents sufficient information for the GOS to prioritize potential irrigation projects and to begin the second phase of these projects. The total implementation process should be carried out on a project-by-project basis without linking two or more projects together. Once priorities are assigned, the second phase of the first priority project should begin immediately, followed by the initiation of the second phase for the second priority project as funds become available. In this manner, each potential project would be carried through from the second phase to operation without being delayed by the implementation process of other projects.

The second phase of study for any of the plans presented in this report can be divided into the following broad categories: (a) yield studies; (b) preliminary design and cost estimates; (c) irrigation area studies; (d) multiple-use studies; (e) implementation and management studies; and (f) impacts and mitigation studies. Many of the tasks to be performed in each category would be similar for any of the plans. These tasks are discussed in general in the following sections.

A. YIELD STUDIES

A more accurate determination of the potential irrigation yield of the plans must be made in order to provide adequate design and cost estimates. The following tasks would be performed under this category.

TASK A.1. DETERMINE SENSITIVITY OF POTENTIAL IRRIGATION YIELD TO STREAMFLOW RECORD

With the exception of the Komati river records, the flow records available do not extend over a long enough period of time to reliably indicate

streamflow and reservoir yield potentials. The relatively short records available do not necessarily include critical low or high flow periods. The most appropriate way to deal with these data deficiencies would be to generate a number of synthetic flow records of long duration based on a variety of statistical possibilities.

Subtask A.1.a. Expand record length. This subtask would include the development of monthly correlation, the generation of simulated flows, and the testing of reliability of the simulated flows. This would result in the development of a range or series of records based on different assumptions and methods. These different methods should include an analysis of similar rivers in the region with longer records lengths.

Subtask A.1.b. Conduct sensitivity analysis. This subtask would include the determination of the potential irrigation yield associated with the range of expanded records developed in Subtask A.1.a. This will result in the identification of the range or magnitude of potential irrigation yields.

TASK A.2. DETERMINE THE RELATIONSHIP BETWEEN STORAGE SIZE AND POTENTIAL IRRIGATION YIELD

After the sensitivity analysis presented in Task A.1. has been performed, detailed studies to determine the irrigation potential with various storage capacities would be conducted using the results of Task A.1.

Subtask A.2.a. Preliminary selection of damsites. This subtask would identify the location of the damsites to be analyzed; existing mapping and a preliminary onsite examination would be used.

Subtask A.2.b. Determine potential storage capacity of site. This subtask would develop the preliminary storage capacity data of the selected sites using existing mapping.

Subtask A.2.c. Develop computer model for multiple reservoir analysis. Detailed plan formulation studies would require the development of mathematical models that could accommodate and analyze the ability of reservoirs singly, in combination, or in sequence to provide water to a number of demand points. These models should also be capable of accommodating downstream flow requirements, offstream storage, and in-system project storage. This model would be particularly useful in analyzing the complex Usutu system.

Subtask A.2.d. Develop storage-yield curves. This subtask would include a detailed computer analysis of storage-versus-yield using the results of Task A.1. This subtask would result in the determination of the potential yield for each storage size examined that would have an acceptable shortage index. The acceptable shortage index would be arrived at by examination of the magnitude of monthly shortages and the potential impacts on irrigated agriculture that these shortages are likely to produce.

TASK A.3. DETERMINE OPTIMUM DAM SIZE

A major portion of the project costs are related to the embankment and emergency spillway structures. In many cases the size and cost of these facilities are affected substantially by the requirements to guard against a breach failure due to hydrologic circumstances.

Subtask A.3.a. Develop unit hydrograph criteria. This subtask would include a hydrologic analysis of each basin in order to develop the criteria necessary for design.

Subtask A.3.b. Develop design floods. This subtask would result in the determination of the magnitude of floods for which design analysis would be undertaken.

Subtask A.3.c. Route design floods. This subtask would include routing the design floods developed in Subtask A.3.b. through the selected damsites to determine potential spillway requirements.

Subtask A.3.d. Conduct wind-wave analysis. This subtask would include an analysis of potential wave action at the damsite to determine freeboard requirements.

Subtask A.3.e. Determine optimum dam size. This subtask includes a comparison of potential dam costs with potential spillway costs to determine the most economical relationship between dam height and spillway size. The costs analyzed would be order-of-magnitude costs such as those used in the framework plan.

TASK A.4. DETERMINE HYDROPOWER IMPACTS ON IRRIGATION YIELD

This task would analyze the multiple-purpose use of the damsite for both irrigation and hydropower.

Subtask A.4.a. Determine the hydropower potential of each damsite. The hydropower potential of the dam should be determined for two levels. The first level would assume that the dam would supply all or most of the energy needs of the potential irrigation project. The second level would assume that the maximum hydropower potential of the site would be realized.

Subtask A.4.b. Determine hydropower requirements and operations. This subtask would include the determination of facilities and costs necessary to meet the hydropower potential identified in Subtask A.4.a. This subtask would also include an analysis of the hydropower operation which would be required at the damsite.

Subtask A.4.c. Determine impacts on irrigation yield. This subtask would include a detailed computer analysis of the impacts of hydropower operations on the potential irrigation yield at the damsite.

B. PRELIMINARY DESIGN AND COST ESTIMATES

Preliminary design and cost estimates for potential dams and main delivery canals would be prepared following completion of the irrigation yield studies. Tasks to be performed under this category include surveys, geologic explorations and analysis, and design work and cost estimating.

TASK B.1. CONDUCT SURVEYS AT DAMSITES AND CANALS

More detailed surveys would be required to adequately provide preliminary designs of the plans. Horizontal and vertical controls would be established at each damsite and aerial topography would be developed to the scale of 1:4800 with 5-foot contour intervals. Surveys would also be made at each location where a main delivery canal would cross a river or stream.

TASK B.2. CONDUCT GEOLOGIC INVESTIGATIONS OF EACH DAMSITE

More geological detail would be required to adequately provide for preliminary design and cost estimates.

Subtask B.2.a. Conduct drilling program. Exploration of each damsite would require a minimum of seven borings. These would be drilled in the abutments, valley bottom, and spillway and borrow areas. The depths of the borings would be proportional to the embankment height.

Subtask B.2.b. Examine geologic conditions at damsite. This subtask would include a search and an interpretation of existing literature, site reconnaissance and preliminary mapping, and an analysis of the results of Subtask B.2.a.

TASK B.3. DEVELOP DESIGN AND COST ESTIMATES

This task would include several design and estimating subtasks necessary to develop preliminary designs and cost estimates.

Subtask B.3.a. Identify borrow areas. This task would include identifying the location of the sources and the availability of materials needed for construction of each dam.

Subtask B.3.b. Design embankment. This subtask would include zoning of materials and slopes, design, and an estimation of quantities.

Subtask B.3.c. Design structures. This subtask would include a determination of requirements and the design of outlet and diversion structures.

Subtask B.3.d. Design electrical and mechanical systems. This subtask would include an identification of electrical and mechanical requirements and a determination of facilities and equipment necessary to meet these requirements.

Subtask B.3.e. Determine relocations required. This subtask would include the identification and design of the road and utility relocations which would be required at each damsite.

Subtask B.3.f. Design main delivery canals. This subtask would include the layout and design of the canals and the design of river, road, and stream crossings. This subtask also includes determination of tributary discharges required in sizing the tributary crossings.

Subtask B.3.g. Develop unit costs and prices. This subtask would include an examination of existing cost indexes and the development of any required additional unit cost data necessary for final development of cost estimates.

Subtask B.3.h. Determine costs. This subtask will use the information developed in subtasks B.3.a. through B.3.g. to determine the construction costs of the dams and canals.

C. IRRIGATION AREA STUDIES

Work to be performed under this category is concerned with the planning, design, and cost estimate of the physical aspects of the area to be irrigated. Much of this work can be accomplished concurrently with the first two categories.

TASK C.1. DEVELOP SOILS ANALYSIS

This task would include detailed soil investigations and mapping. Major soil characteristics to be identified in this task include depth of soil, permeability, and chemical properties.

Subtask C.1.a. Conduct soil sampling program. This subtask would include gathering samples of the soils in the irrigated area. A 400-meter traverse grid would be established and soil samples would be taken approximately every 400 meters. The test holes would be about 1.5 meters deep by 15 centimeters wide. By feel and observation, the classifier would identify soil texture, aggradation, permeability, chemical character, soil moisture, parent material, and substrate. At least one deep sample would be taken every 1,600 meters.

Subtask C.1.b. Conduct soil testing program. A field laboratory would run routine tests to substantiate the field tests. Tests would be made for pH, salinity, insoluble carbonates, gypsum, sodium, texture, and moisture. Special tests would be made where the need arises for such things as unusual chemical constituents, physical behavior, organic matter, and type of clay mineral.

Subtask C.1.c. Develop soil maps. Detailed mapping of the soils would be developed after testing has been completed. This mapping would be of sufficient detail to identify the areas or blocks of soils that are irrigable and to allow for preliminary layout of the irrigation project.

Subtask C.1.d. Determine drainage characteristics. This subtask would include an analysis of soil types and slopes to determine subsurface drainage characteristics and requirements.

TASK C.2. LAND ALLOCATION

Utilizing the soils mapping developed in Task C.1., a general land use plan would be developed. Farm plots would be identified. Approximate routes or corridors for major distribution canals, feeder canals, and roads would be laid out. Housing areas and sites for other project facilities, such as administration buildings, maintenance shops, and warehouses, would be identified. Small sites for overnight irrigation water storage would also be identified.

TASK C.3. DETERMINE GROUND WATER POTENTIAL FOR DOMESTIC WATER SUPPLY

This task would include pump testing and water quality sampling to determine whether ground water supplies at the project area would be adequate to supply the domestic water supply needs of the project homesteads.

TASK C.4. FACILITIES DESIGN AND COST ESTIMATES

Design and cost estimates for irrigation area facilities would not be developed to the same level of detail as the dams and canals during this phase of the study. Rather, general cost estimates on a per land unit basis by facility type would be developed; these would be based on estimates presented for existing or planned irrigation schemes in Swaziland. These estimates would then be applied to the irrigation area.

TASK C.5. IDENTIFY POTENTIAL CROPS

This task would result in the identification of those types of crops possessing the greatest potential for the particular irrigation project. This task would use the information developed in the production and marketing general studies.

TASK C.6. DEVELOP CROPPING PLANS AND COST ESTIMATES

Once Tasks C.1. through C.5. have been completed, the cropping plan for the particular irrigation project would be developed. This task would include the identification of the types of crops to be grown, the total quantity of land to be devoted to each crop, and the development of the cropping costs associated with this plan.

TASK C.7. IDENTIFY POTENTIAL PROJECT RETURNS

This task includes the identification of the potential benefits to be derived from the project, including total sales and other income benefits.

D. MULTIPLE-USE STUDIES

There are many opportunities for multiple-use storage reservoirs and irrigation systems. Municipal and industrial water supply, rural domestic water supply, fishery enhancement, and recreation cannot offer substantial financial contributions to the development; however, the potential for improving the general welfare of the people is great. For example, water-borne disease is the major health problem in rural areas. The provision of good quality water could result in a significant improvement in rural health.

Work performed under this category would be directed toward examination of multiple-use opportunities for water supply, fisheries, and recreation. This would include identifying opportunities, determining modifications in project design or operation to meet these opportunities, and determining cost estimates for these modifications.

TASK D.1. DETERMINE WATER SUPPLY POTENTIAL AND PLANS

This task would analyze the potential of the project to provide domestic water supplies.

Subtask D.1.a. Determine water supply service area. This subtask would determine the area that could be served by the project. The area would include the irrigation project area. From aerial photos, the homesteads to be served by the project would be located on a potential service map.

Subtask D.1.b. Determine quantity of water required. This subtask would include the determination of per capita use rates. These rates would be applied to the population that would be served by the project to determine total water requirements.

Subtask D.1.c. Evaluate water quality. The existing water quality would be determined, and the treatment required to provide adequate water quality would be estimated.

Subtask D.1.d. Develop design and cost estimates. This subtask would include design and cost estimates and existing data would be used to develop approximate size, location, routes, and water delivery and treatment systems.

TASK D.2. DETERMINE FISHERIES POTENTIAL AND PLANS

Each damsite would provide the opportunity for development of a fisheries industry.

Subtask D.2.a. Determine target species. This subtask would identify the species with the highest potential for development of the fisheries industry. Criteria to be used in determining the target species would include food and economic value, ecological or scientific importance, cultural value, rarity or uniqueness, and nuisance quality.

Subtask D.2.b. Determine conditions in proposed project and impacts on target species. This subtask would analyze the project design and operations and determine its conduciveness to support of the target species.

Aspects of the project design and operations of the project which should be analyzed include water quality parameters such as temperature, turbidity, light penetration, pH, alkalinity and hardness, dissolved oxygen, total dissolved solids, nutrient levels pollutants, flows, climatic factors, and nuisances. Other aspects include morphometry of the lake, such as slope, depth, area, and volume. Special emphasis should be placed on analyzing drawdown due to irrigation releases. Aspects of the target species that would be important in this analysis include the life cycle, breeding and spawning rates and needs, life history stages and needs, and migratory movements.

Subtask D.2.c. Determine fisheries potential. The results of subtasks D.2.a. and D.2.b. would be utilized and examined with other items to determine the fisheries potential. These other items include public access; potential for organizing a corporate fishing venture; availability of equipment, facilities, transportation, and marketing; and cultural constraints.

Subtask D.2.d. Determine benefits from the potential fisheries industry. This subtask would include the analysis of the potential return on investment to be derived from the fisheries industry. This would include the actual fishing industry as well as potential processing and marketing industries.

TASK D.3. DETERMINE RECREATION POTENTIAL AND PLANS

This task would examine the potential recreation and tourism benefits to be derived from the project.

Subtask D.3.a. Determine existing recreation conditions in the project area. This task would include the identification of existing recreational facilities and the visitation to these areas.

Subtask D.3.b. Determine the suitability of the reservoir for recreation. This subtask would include an analysis of the reservoir size and

depth, temperature, trophic condition, turbidity, pollutants or disease organisms, attractiveness to waterfowl and other wildlife, and the potential operation of the reservoir for irrigation. This analysis would be used to determine whether an examination of the development of recreation facilities is warranted.

Subtask D.3.c. Determine recreation facilities and costs. This task would include the development of a recreation plan, including facilities and management requirements, and the development of cost estimates.

Subtask D.3.d. Determine potential recreation benefits. This task would include an estimate of the benefits to be derived from the recreation plan in terms of visitor days and the value of visitor days.

E. IMPLEMENTATION AND MANAGEMENT STUDIES

In order to facilitate the progress of the study from the preliminary design phase to the detailed design and construction phases, the potential for and the methods of implementation and management should be clearly identified. Much of the work identified under this category would begin during the second phase and would continue through the later phases.

Effective, aggressive implementation and management would be required to fully realize the potential benefits of irrigation. Significant changes must take place in short periods of time, particularly in areas currently in subsistence agriculture. These changes would result in improved employment and earning opportunities but would also have a potential for causing short-term disruption. Strategies that would bring irrigated land into full production rapidly and maintain a high level of production must be developed during detailed planning. Thus must be done in a manner that will assure the desired changes and avoid undue disruption of human lives and values.

These studies should be developed jointly by representatives of the GOS, private industry, and the traditional sector. It is very important to bring private industry into the project during this phase of the study because it will ultimately be responsible for management of the project. It is equally important to bring representatives from the traditional sector into the project during this phase. It is the traditional sector from which the project farmers will be drawn. The government would act as the link between private industry and the traditional rural sector by taking the broad overview of the project goals and implementation.

TASK E.1. DEVELOP PUBLIC INVOLVEMENT AND INPUT PROGRAM

The public involvement and input program would be developed and initiated during the second phase of the study and would continue through all subsequent study phases. The program should be structured in such a way that it would provide mechanisms whereby the traditional sector would have a voice in the planning and design of the project. This would help to mitigate many of the social disruptions that would occur during transition from a traditional to a modern agricultural setting and would help to preserve some of the important cultural values of Swazi life.

TASK E.2. DEVELOP THE RESETTLEMENT PROGRAM

Homesteads which would be displaced by the project would be identified. A plan for the resettlement of these homesteads would be devised. This task would also include the development of a farmer selection program for the project, including criteria for selection and potential resettlement procedures.

TASK E.3. DEVELOP POTENTIAL MANAGEMENT PLANS

This task would include the identification of personnel and facilities requirements for project management. The organizational or hierarchical structure of the project management function would be developed.

F. IMPACTS AND MITIGATION STUDIES

Work to be performed under this category would be conducted concurrently with work performed under all the other categories. The impact analysis would be conducted for three broad areas: health, fish and wildlife, and social and cultural. Plans to mitigate the significant impacts of the projects would be developed.

Many of the tasks under this category could be part of other studies to assist in long-term planning for Swaziland, such as wildlife inventories and waterborne disease studies. The total time and study costs presented here represent only a preliminary analysis; additional, more detailed studies would be required during later irrigation study phases or other studies.

The method of conducting the impact analyses presented in this category would generally follow similar procedures. These procedures can be summarized as follows: Step 1 - identify the area likely to be impacted by the project; Step 2 - determine the current situation in that area; Step 3 - project what the future situation would be without the existence of the project; Step 4 - project what the future situation would be with the project; Step 5 - utilizing the results of Steps 2, 3, and 4, determine the likely impacts of implementation of the project, and; Step 6 - determine measures which could be taken to mitigate the impacts identified in Step 5.

TASK F.1. DETERMINE HEALTH IMPACTS

This task would identify the impacts, both positive and negative, of the potential project on health aspects of the population.

Subtask F.1.a. Determine potential increases in the prevalence of schistosomiasis. This task would examine the potential of the projects to increase health threats from schistosomiasis. This would include a detailed examination of the project design and operation to determine

potential snail breeding and habitat areas. This subtask would also examine the accessibility of these areas for the local population. Potential changes to design or operation of the project which would eliminate or alleviate the increased schistosomiasis potential would be outlined.

Subtask F.1.b. Determine potential increases in the prevalence of malaria. This subtask would include an examination similar to that presented in Subtask F.1.a. for malaria and mosquito habitat areas.

Subtask F.1.c. Determine nutritional impacts of increased agricultural production in Swaziland. This subtask would analyze the potential cropping plan for the project and would determine the impacts on the current nutritional status in Swaziland.

Subtask F.1.d. Determine the impacts of providing a domestic water supply from the project. This subtask would analyze the potential water supply plan associated with the project and determine the impacts on health that this project would have on the population served by the project.

TASK F.2. IDENTIFY FISH AND WILDLIFE IMPACTS

This task would result in the identification of potential fish and wildlife impacts and a mitigation plan. This task would be conducted in the steps presented in the introduction to this category. Specific mention should be made, however, of the need for fish and wildlife inventories as part of this task. Knowledge of Swaziland's wildlife is limited and these inventories would be desirable even as a task separate from the projects. Particular attention should be paid to rare or endangered species.

TASK F.3. IDENTIFY SOCIAL AND CULTURAL IMPACTS

Significant work has already been accomplished in analyzing the traditional social and cultural values of the rural Swazis. This task would include a detailed examination of these previous works. This examination would be used, supplemented where required, and applied to the specific

project area to determine impacts. This task should be conducted in conjunction with the public involvement program developed in Task E.1.

COSTS AND SCHEDULES

This section presents second phase study costs and schedules for each of the potential plans presented in Part I of this report. The second phase should be initiated independently on a project-by-project basis and should not be linked together.

LOMATI RIVER PROJECT

Table III-1 presents study costs by task for the second phase study for the Lomati river project. These study costs do not include travel or living allowance costs. It is estimated that a study team consisting of 25 persons, including survey, boring, and soil sampling crews, would require a total of about 40 man-months of effort to complete the field work in Swaziland.

Because only one reservoir is involved, the development of a multiple reservoir computer model, as outlined in Subtask A.2.c., would not be included. The study costs presented in table III-1 are for examination of the with-storage plan using both run-of-river flows and storage at DS 5.2. Study costs for the without-storage plan were not developed but they would be approximately 50 to 60 percent of the costs presented in table III-1.

The study schedule for the Lomati basin is shown in table III-2. It is estimated that the study could be completed in about 18 months.

Table III-1
Second Phase Study Costs
Lomati River Project

Task	Description	Total Labor (Man-weeks)	Total Cost (E1000)
A.1.	Determine sensitivity of potential irrigation yield to streamflow record	6	6
A.2.	Determine relationship between storage size and potential irrigation yield	14	15
A.3.	Determine optimum dam size	8	9
A.4.	Determine hydropower impacts on irrigation yield	15	9
B.1.	Conduct surveys at damsites and canals	12	73
B.2.	Conduct geologic investigations of the damsites	12	54
B.3.	Develop design and cost estimates	45	54
C.1.	Develop soils analysis	27	45
C.2.	Land allocation	4	2
C.3.	Determine ground water potential for domestic water supply	10	14
C.4.	Facilities design and cost estimates	14	6
C.5.	Identify potential crops	4	2
C.6.	Develop cropping plans and cost estimates	12	6
C.7.	Identify potential project returns	8	4
D.1.	Determine water supply potential and plans	20	12
D.2.	Determine fisheries potential and plans	20	12
D.3.	Determine recreation potential and plans	20	12
E.1.	Develop public involvement and input program	32	22
E.2.	Develop the resettlement program	12	6
E.3.	Develop potential management plans	20	14
F.1.	Determine health impacts	48	26
F.2.	Identify fish and wildlife impacts	60	30
F.3.	Identify social and cultural impacts	48	26
	SUBTOTAL	471	459
	Report Preparation		14
	TOTAL STUDY COSTS		473

Table III-2
Second Phase Study Schedule
Lomati River Project

Task		Study Month Initiate	Study Month Complete
A.1.	Streamflow yield	1	2
A.2.	Storage yield	1	4
A.3.	Optimization	2	5
A.4.	Hydropower potential	3	5
B.1.	Surveys	4	5
B.2.	Geology	6	7
B.3.	Designs and costs	7	10
C.1.	Soils analysis	2	6
C.2.	Land allocation	7	7
C.3.	Ground water analysis	7	8
C.4.	Facilities plans	8	12
C.5.	Potential crops	4	5
C.6.	Cropping plan	6	9
C.7.	Project returns	10	11
D.1.	Water supply plan	4	7
D.2.	Fisheries plan	7	12
D.3.	Recreation plan	8	13
E.1.	Public involvement	1	18
E.2.	Resettlement plan	8	11
E.3.	Management plan	11	14
F.1.	Health impacts	9	11
F.2.	Fish and wildlife	8	13
F.3.	Social and cultural	8	13
REPORT		16	18

MBULUZI RIVER PROJECT

Table III-3 presents study costs by task for the second phase study for the Mbuluzi river project. Table III-3 does not include travel or living allowance costs. It is estimated that a study team consisting of 15 persons, including survey and soil sampling crews, would spend a total of about 20 man-months doing field work in Swaziland.

Because this plan would examine additional irrigation from Mnjoli dam, the design and cost estimates presented in Task B.3. are for canal design only. Hydrologic studies would concentrate on determining the additional yield that could be provided from Mnjoli dam. There is a possibility that these hydrologic studies could show a much more limited potential for additional irrigation yield from Mnjoli dam than is presented in this report. As shown on table III-4, these hydrologic yield study tasks would be completed prior to initiation of any other tasks because of the possibility of termination of the study at this point.

USUTU RIVER PROJECT

The Mapobeni irrigation scheme, which has been examined prior to this report, is further along in the study process than the Usutu river projects. Implementation of the Mapobeni scheme should be initiated immediately.

Table III-5 presents the cost estimate for the second phase study for the Usutu river DS 1.3 project. These costs do not include travel or living allowance costs. It is estimated that a study team consisting of about 30 persons would spend a total of about 55 man-months doing field work in Swaziland. Table III-6 presents the study schedule. It is estimated that the study could be completed in about 20 months.

Table III-3
Second Phase Study Costs
Mbuluzi River Project

Task	Description	Total Labor (Man-weeks)	Total Cost (E1000)
A.1.	Determine sensitivity of potential irrigation yield to streamflow record	6	6
A.2.	Determine relationship between storage size and potential irrigation yield	14	15
A.3.	Determine optimum yield	6	6
B.1.	Conduct surveys at damsites and canals	7	13
B.3.	Develop design and cost estimates	14	17
C.1.	Develop soils analysis	13	22
C.2.	Land allocation	2	2
C.3.	Determine ground water potential for domestic water supply	10	14
C.4.	Facilities design and cost estimates	7	4
C.5.	Identify potential crops	4	2
C.6.	Develop cropping plans and cost estimates	12	6
C.7.	Identify potential project returns	8	4
D.1.	Determine water supply potential and plans	15	9
E.1.	Develop public involvement and input programs	24	17
E.2.	Develop the resettlement program	6	3
E.3.	Develop potential management plans	15	10
F.1.	Determine health impacts	24	13
F.2.	Identify fish and wildlife impacts	30	15
F.3.	Identify social and cultural impacts	24	13
	SUBTOTAL	241	191
	Report Preparation		11
	TOTAL STUDY COSTS		202

Table III-4
Second Phase Study Schedule
Mbuluzi River Project

Task		Study Month	
		Initiate	Complete
A.1.	Streamflow yield	1	2
A.2.	Storage yield	2	4
A.3.	Optimization	2	3
B.1.	Surveys	4	5
B.3.	Designs and costs	5	6
C.1.	Soils analysis	5	6
C.2.	Land allocation	7	7
C.3.	Ground water analysis	5	6
C.4.	Facilities plans	5	6
C.5.	Potential crops	5	6
C.6.	Cropping plan	7	10
C.7.	Project returns	10	11
D.1.	Water supply plan	5	7
E.1.	Public involvement	1	12
E.2.	Resettlement plan	6	7
E.3.	Management plan	7	10
F.1.	Health impacts	7	9
F.2.	Fish and wildlife	5	8
F.3.	Social and cultural	5	8
REPORT		10	12

Table III-5
Second Phase Study Costs
Additional Irrigation in the Lower Great Usutu Basin

Task	Description	Total Labor (Man-weeks)	Total Cost (E1000)
A.1.	Determine sensitivity of potential irrigation yield to streamflow records	41	58
A.2.	Determine relationship between storage size and potential irrigation yield	156	173
A.3.	Determine optimum dam size	33	35
A.4.	Determine hydropower impacts on irrigation yield	15	10
B.1.	Conduct surveys at damsites and canals	10	67
B.2.	Conduct geologic investigations of damsites	24	161
B.3.	Develop design and cost estimates	43	52
C.1.	Develop soils analysis	12	20
C.2.	Land allocation	8	4
C.3.	Determine ground water potential for domestic water supply	5	8
C.4.	Facilities design and cost estimates	17	8
C.5.	Identify potential crops	4	2
C.6.	Develop cropping plans and cost estimates	16	8
C.7.	Identify potential project returns	8	4
D.1.	Determine water supply potential and plans	20	12
D.2.	Determine fisheries potential and plans	20	12
D.3.	Determine recreation potential and plans	20	12
E.1.	Develop public involvement and input program	40	28
E.2.	Develop the resettlement program	16	7
E.3.	Develop potential management plans	32	22
F.1.	Determine health impacts	32	19
F.2.	Identify fish and wildlife impacts	41	20
F.3.	Identify social and cultural impacts	32	19
	SUBTOTAL	645	761
	Report Preparation		14
	TOTAL STUDY COSTS		775

Table III-6
Second Phase Study Schedule
Additional Irrigation in the Lower Great Usutu Basin

Task		Study Month Initiate	Study Month Complete
A.1.	Streamflow yield	1	4
A.2.	Storage yield	1	12
A.3.	Optimization	10	13
A.4.	Hydropower potential	12	13
B.1.	Surveys	5	6
B.2.	Geology	6	7
B.3.	Designs and costs	6	12
C.1.	Soils analysis	1	6
C.2.	Land allocation	6	7
C.3.	Ground water analysis	7	8
C.4.	Facilities plans	8	13
C.5.	Potential crops	4	5
C.6.	Cropping plan	6	9
C.7.	Project returns	10	11
D.1.	Water supply plan	13	15
D.2.	Fisheries plan	6	11
D.3.	Recreation plan	6	11
E.1.	Public involvement	1	20
E.2.	Resettlement plan	12	15
E.3.	Management plan	10	18
F.1.	Health impacts	9	15
F.2.	Fish and wildlife	9	15
F.3.	Social and cultural	9	15
REPORT		15	20

NGWAVUMA RIVER BASIN PROJECTS

These two projects have been analyzed and presented separately. If, in this case, it is decided to implement both projects, the two project studies should be closely coordinated in order to avoid duplication of study effort and to analyze possible combinations of some parts of the potential projects.

Table III-7 presents the costs by task for the second phase study for the Ngwavuma river DS V project. These costs do not include travel or living allowance costs. It is estimated that a study team consisting of 25 persons, including surveys, boring, and soil sampling crews, would spend a total of about 26 man-months doing field work in Swaziland.

Table III-8 presents the study schedule. It is estimated that the study could be completed in about 14 months.

Table III-9 presents the cost estimate for the second phase study for the Usutu river diversion to the Ngwavuma basin from DS 2.2 and DS 3.2. These costs do not include travel or living allowance costs. It is estimated that a study team consisting of about 30 persons would spend a total of about 72 man-months doing field work in Swaziland.

It is estimated that this study could be completed in 2 years. The study schedule is presented in table III-10.

Table III-7
Second Phase Study Costs
Ngwavuma River DS V Project

Task	Description	Total Labor (Man-weeks)	Total Cost (E1000)
A.1.	Determine sensitivity of potential irrigation yield to streamflow records	6	6
A.2.	Determine relationship between storage size and potential irrigation yield	14	15
A.3.	Determine optimum dam size	8	9
A.4.	Determine hydropower impacts on irrigation yield	15	9
B.1.	Conduct surveys at damsites and canals	5	60
B.2.	Conduct geologic investigations of the damsites	12	54
B.3.	Develop design and cost estimates	23	27
C.1.	Develop soils analysis	9	13
C.2.	Land allocation	2	2
C.3.	Determine ground water potential for domestic water supply	10	14
C.4.	Facilities design and cost estimates	8	4
C.5.	Identify potential crops	4	2
C.6.	Develop cropping plans and cost estimates	12	6
C.7.	Identify potential project returns	8	4
D.1.	Determine water supply potential and plans	9	6
D.2.	Determine fisheries potential and plans	9	7
D.3.	Determine recreation potential and plans	9	7
E.1.	Develop public involvement and input program	24	17
E.2.	Develop the resettlement program	6	3
E.3.	Develop potential management plans	10	7
F.1.	Determine health impacts	24	13
F.2.	Identify fish and wildlife impacts	40	20
F.3.	Identify social and cultural impacts	36	20
	SUBTOTAL	303	325
	Report Preparation		14
	TOTAL STUDY COSTS		339

Table III-8
Second Phase Study Schedule
Ngwavuma River DS V Project

Task		Study Month	
		Initiate	Complete
A.1.	Streamflow yield	1	2
A.2.	Storage yield	1	4
A.3.	Optimization	3	4
A.4.	Hydropower potential	1	4
B.1.	Surveys	2	4
B.2.	Geology	4	5
B.3.	Designs and costs	5	7
C.1.	Soils analysis	1	3
C.2.	Land allocation	3	3
C.3.	Ground water analysis	2	2
C.4.	Facilities plans	3	5
C.5.	Potential crops	5	6
C.6.	Cropping plan	7	10
C.7.	Project returns	10	11
D.1.	Water supply plan	4	6
D.2.	Fisheries plan	5	7
D.3.	Recreation plan	5	7
E.1.	Public involvement	1	14
E.2.	Resettlement plan	7	9
E.3.	Management plan	10	11
F.1.	Health impacts	6	9
F.2.	Fish and wildlife	5	10
F.3.	Social and cultural	5	10
REPORT		11	14

Table III-9
Second Phase Study Costs
Additional Irrigation in the Ngwavuma and Pongola Basins

Task	Description	Total Labor (Man-weeks)	Total Cost (E1000)
A.1.	Determine sensitivity of potential irrigation yield to streamflow records	41	58
A.2.	Determine relationship between storage size and potential irrigation yield	184	204
A.3.	Determine optimum dam size	66	70
A.4.	Determine hydropower impacts on irrigation yield	30	19
B.1.	Conduct surveys at damsites and canals	20	149
B.2.	Conduct geologic investigations of damsites	24	161
B.3.	Develop design and cost estimates	71	88
C.1.	Develop soils analysis	20	34
C.2.	Land allocation	8	4
C.3.	Determine ground water potential for domestic water supply	8	12
C.4.	Facilities design and cost estimates	26	12
C.5.	Identify potential crops	4	2
C.6.	Develop cropping plans and cost estimates	16	8
C.7.	Identify potential project returns	8	4
D.1.	Determine water supply potential and plans	28	17
D.2.	Determine fisheries potential and plans	28	17
D.3.	Determine recreation potential and plans	28	17
E.1.	Develop public involvement and input program	40	28
E.2.	Develop the resettlement program	16	7
E.3.	Develop potential management plans	32	22
F.1.	Determine health impacts	47	27
F.2.	Identify fish and wildlife impacts	59	28
F.3.	Identify social and cultural impacts	47	27
	SUBTOTAL	851	1,015
	Report Preparation		14
	TOTAL STUDY COSTS		1,029

Table III-10
Second Phase Study Schedule
Additional Irrigation in the Ngwavuma and Pongola Basins

Task		Study Month Initiate	Study Month Complete
A.1.	Streamflow yield	1	4
A.2.	Storage yield	1	12
A.3.	Optimization	10	13
A.4.	Hydropower potential	12	14
B.1.	Surveys	7	9
B.2.	Geology	8	10
B.3.	Designs and costs	8	14
C.1.	Soils analysis	1	6
C.2.	Land allocation	6	7
C.3.	Ground water analysis	7	8
C.4.	Facilities plans	14	20
C.5.	Potential crops	6	7
C.6.	Cropping plan	8	11
C.7.	Project returns	12	13
D.1.	Water supply plan	13	15
D.2.	Fisheries plan	8	13
D.3.	Recreation plan	8	13
E.1.	Public involvement	1	24
E.2.	Resettlement plan	10	13
E.3.	Management plan	11	16
F.1.	Health impacts	10	15
F.2.	Fish and wildlife	10	15
F.3.	Social and cultural	10	15
REPORT		20	24

IMPLEMENTATION SCHEDULE

Table III-11 presents a potential schedule for implementation of the plans presented in this report. This schedule is highly compressed and accelerated. The high population growth rate in Swaziland is beginning to place significant stress on the resources and economy of the country. Programs currently in operation to reduce the high population growth rate will require time for their effects to be felt. The accelerated schedule would help to alleviate some of the growth-related stress and at the same time would allow for some of the time required for these programs to take effect.

Analysis and renegotiation with the RSA for the Komati river flows should begin immediately. If, through this analysis and renegotiation, it is discovered that additional irrigation activities in the Komati river basin are possible, study activities should be initiated in 1982.

The Mapobeni irrigation scheme should be initiated immediately. This scheme is closer to completion than the projects presented in this report and it should be the initial focus of irrigation project implementation in Swaziland.

Implementation of any schedule should occur on a project-by-project basis and should be carried through to completion without being delayed by study activities of any other project.

Table III-11
Potential Project Schedule

Subject	Phase 2	Design	Construction	Phase 2 Initiated	Construction Completed
Komati analysis and renegotiations	-	-	-	1981	1982
Mapobeni irrigation scheme	-	1 year	1.5 years	1981	mid-1983
Lomati river project	1.5 years	1 year	1.5 years	1982	1985
Mbuluzi river project	1 year	0.5 year	1 year	mid-1981	1983
Usutu river project (DS 1.3)	1.7 years	1 year	2 years	mid-1983	1986
Ngwavuma river basin projects					
(DS V)	1.2 years	1 year	1.5 years	mid-1984	1987
(DS 2.2 and DS 3.2)	2 years	1 year	2 years	mid-1984	1989
General studies	-	-	-	1981	ongoing

PART IV

BASE STUDIES

PART IV

BASE STUDIES

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SECTION A

SOCIAL AND CULTURAL PROFILE

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SECTION A
SOCIAL AND CULTURAL PROFILE

Numerous reports concerning the social and cultural aspects of Swaziland have been developed. This section will not duplicate those efforts but will provide a brief overview of the social and cultural aspects that are significant to water resources planning.

DUALISM

The concept of "dualism" enters almost every description of the Kingdom of Swaziland. This dualism is presented in terms of the "traditional" sector versus the "modern" sector and is apparent in almost every aspect of Swaziland today. Dualism is apparent in the economy, government, and land tenure. Dualism can be traced to the effects of European culture (being superimposed) on the traditional Swazi culture. The forms of dualism are briefly discussed in the following paragraphs.

DUALISM IN THE ECONOMY

The economy of Swaziland is sharply divided into a traditional sector and a modern sector. The traditional sector is mainly composed of subsistence agriculture on Swazi Nation Land (SNL). The modern sector includes the large-scale farming operations; the lumber and mining industries; and the manufacturing, processing, wholesale, retail, and other industries associated with the urban areas. Although development

within the modern sector has been significant, it has had little apparent effect on the traditional sector. There are some indications, however, that this dualism is less distinct than previously supposed. A close examination of some aspects of the traditional sector tends to blur the distinction between the two sectors.

Because of significant population growth in recent years, most rural households in the traditional sector have more family members than are needed to run the farming operations and more members than can be supported by these operations. As a result of this and of the allure of wages, many Swazis, particularly the males, leave the farms to take up employment in the modern sector. These absentees may be gone from the farm for years. Most absentees regularly send remittances from their wages to their rural homesteads. Recent surveys indicate that about 65 percent of all homesteads have at least one member in wage employment and that more than 50 percent of the homesteads receive regular remittances from these absentee members. In many instances, particularly in poor homesteads, these remittances amount to a significant portion of the total homestead income--as much as 50 percent in some homesteads. This would clearly indicate that the modern and traditional sectors of the economy are interrelated. The dualism of the economy is, therefore, not as clear-cut as would seem evident.

DUALISM IN GOVERNMENT

The government structure is also dualistic. The modern sector, including the central government at Mbabane, is descended from the colonial administration of the recent past. The various ministries of government are ultimately responsible to the King and administer those aspects of Swaziland that are common to all governments, such as water and power development and health services. The traditional sector is complex and has developed and evolved since the original migration of the Swazi tribe into the area. The backbone of the traditional sector

is its system of chiefs. Swaziland is roughly divided into areas over which different chiefs have authority. Each chief is directly responsible to the King. Chiefs gain their position through kinship and, at present, there are between 200 and 300 chiefs in Swaziland.

Each chief has authority in his area over the people who have paid allegiance to him. He administers his area with the assistance of two councils: the "liquoqo," which is composed of close relatives of the chief and other important persons in the area, and the "libandla," which is the full council composed of all adult males. This format also holds true at the national level with the King and his councils. The Swazi National Council consists of all adult Swazi males who, theoretically, have a voice in the governing of Swaziland. The King and the chiefs always strive to achieve a concensus as a basis for decisionmaking in the traditional sector of government.

DUALISM IN LAND TENURE

Dualism is strongly evident in the land tenure system. More than 60 percent of all land in Swaziland falls within the SNL area. This land is held and cultivated under Swazi customary law. The chief feature of SNL is that the land is not owned by individuals. SNL is held in trust by the King for the people of Swaziland. The remainder of the land area is held under title deed by either individuals or companies. This Freehold Title Land (FTL) can be bought and sold freely on the market and is used according to the laws of free enterprise and commerce.

BONDS TO SWAZI NATION LAND AND TRADITION

The traditional land tenure system has offered the Swazi considerable security. This system is being tested as both the population and the modern sector continue to grow. Under the traditional SNL tenure system, every Swazi male possesses rights to certain necessities of life. These include the rights to pasture, water, and hunting and fishing and the right to accommodation, which entails the rights of residency and tillage. Each area chief is responsible for seeing that these rights are met.

The most significant aspect about traditional provisions for land use and control is that they entitle the Swazi to the right to reside on SNL. The Swazi always has a place to stay without having to obtain a job or have an income.

The Swazi is further entitled to derive a living, whether by tillage, pastoral agriculture, or both, from the land on which he is entitled to reside. He is, therefore, assured not only of having a permanent home but also of having at least the minimal means of obtaining a livelihood.

The Swazi enjoys these benefits as a right and cannot be made homeless or destitute by foreclosure on his house or belongings, because these are on land which belongs not to him outright but to the Swazi Nation. In short, the Swazi is part of the Swazi Nation and so is entitled to a share of the nation's resources and, above all, its productive land.

There are strong incentives for maintaining roots in the traditional sector; these include the essential security of land rights and

the position within a chief's libandla. So far, very few Swazis have been willing to give up these securities in the traditional sector no matter how successful they may have become in the modern sector. This is because the traditional sector is more truly a system than is the modern sector. The rural mode of life is an extension of the lifestyle evolved by Swazis more than 150 years ago as their means of survival in the region. As conditions have changed, the traditional sector has been constantly modified, but it still ensures for all Swazis the essentials of survival. By contrast, the modern sector has become established more recently in Swaziland in a piecemeal fashion in consequence of settlement, conquest, and trade. It does not provide a truly alternative mode of life with comparable safeguards against life's hazards. Therefore, when they are taken up, the modern opportunities are frequently used selectively and only to the extent that they serve to meet needs arising from traditional duties and aims.

It is this aspect of Swazi life, the secure right to land and to a livelihood, that most sharply divides the traditional sector from the modern sector. It is also the aspect of Swazi life that is most threatened by the increasing population and by the modern sector.

In the past, population growth in Swaziland did not exert significant pressure on land resources. Recently, however, mortality rates have declined while fertility rates have remained constant; this has caused a significant upward trend in the rate of population growth. As indicated in the Population Section, the population will double within 21 years at the present growth rate. Pressure on the land and, therefore, on the existing system of land tenure will continue. Some of the rights which previously were granted to all adult males will not be met. This will cause significant stress on the traditional social structure as the young males discover that they cannot be granted the same rights that their fathers were granted.

CONSTRAINTS TO THE MODERNIZATION OF THE AGRICULTURAL SECTOR

The constraints or limitations to the modernization of the agricultural sector can be divided into four broad categories--land tenure, other cultural aspects, subsistence level agriculture, and limited technological base. These categories are discussed in the following paragraphs.

LAND TENURE

A nationally stated goal is to increase agricultural productivity in Swaziland. Under a system which does not allow for land ownership, however, it is difficult to provide loans for farm improvement because the land cannot be used as collateral. Cattle may be used as collateral in Swaziland. However, the rapid growth in the cattle population in recent years is placing pressure on the grazing land and, therefore, cattle numbers are not a desirable basis for providing loans. The lack of land ownership also fails to provide the continuity of ownership necessary for long-term improvement of agricultural production. Farm plots are currently being fragmented into smaller parcels as more young Swazis claim land rights from the various chiefs.

One experiment in adapting modern farming techniques to the traditional land tenure system has been attempted at the Vuvulane Irrigated Farms (VIF) in northeastern Swaziland. At VIF, Swazi farmers were provided with small farm plots which are irrigated through an areawide system. VIF has been well accepted by the Swazis. Although the adjustment to this type of system has frequently been difficult, VIF has generally been considered to be a success. VIF has, nonetheless, resulted in some significant erosion in the power of the traditional chief system and, from this standpoint, has met mixed reactions from the traditional sector.

OTHER CULTURAL ASPECTS

The experience at VIF points out another constraint to the modernization of the agricultural sector. This constraint consists of the difficulties faced by the professional farm managers in any VIF-type irrigation project. The manager must, necessarily, exercise some authority over the use of land and, therefore, over the lives of the farmers associated with the project. Because the manager is outside the traditional lines of authority, there is the potential for conflict between the manager and the chiefs. With VIF, this potential conflict was somewhat mitigated when a special representative of the King was appointed as a liaison with the project farmers. This potential conflict will continue, however, until the traditional sector adapts to the modern sector or until mechanisms are developed for the inclusion of traditional lines of authority into the project.

Another constraint under this category is the traditional suspicion of Swazis toward what could be viewed as a European-dominated project. This was one of the underlying problems faced by VIF in adapting the land tenure system to modern agricultural practices. This constraint has its roots in the history of Swaziland. During the latter part of the 19th century, a system of concessions resulted in the granting of large tracts of lands from the Swazi people to European settlers. This is the origin of the FTL and many Swazis remain resentful about being "deprived" of a substantial portion of their national heritage. While much of this land is being repurchased by the government, this resentment is sometimes extended to the modernization of the agricultural sector. In order for this modernization to continue, it must be seen to be the product of and a benefit to the Swazi Nation.

SUBSISTENCE LEVEL AGRICULTURE

The Swazi people have historically lived at a subsistence level. This creates two potential constraints to the modernization of agriculture. The two constraints are interrelated in that they both derive

from the fact that the subsistence farmer lives within a limited time horizon. This type of farmer is oriented toward surviving the following winter and spring and cannot balance one year against the next or survive temporary setbacks for the sake of long-term advance.

The first constraint involves the change from traditional subsistence level agriculture to modern agriculture. The subsistence farmer must reorient his entire thought processes, which are based upon and are the result of generations of subsistence agriculture.

The second constraint is more concrete. In order to change from subsistence to modern agricultural practices, the results of the change must be readily apparent and immediate. This is not easy when input investment is required to produce long-term results.

The experiences at VIF have greatly reduced the constraints under this category. To the extent that VIF-type projects increase in number and influence, these constraints should disappear.

LIMITED TECHNOLOGICAL BASE

Constraints under this category are the same as those faced in all developing countries. The lack or shortage of technical experience and knowledge creates its own constraints to modernization. This holds true for the initial adjustments to modern technology and equipment and for the long-term operation and maintenance of modern equipment. These constraints, however, may be easier to surmount than the constraints mentioned previously because they could be overcome by education and the training of specialized personnel.

The final constraint, which has been frequently brought up as a constraint to the modernization of the agricultural sector, is the lack of marketing and transportation opportunities. Farmers are not likely

to grow more food unless it can be transported and marketed. Past experience in Swaziland, however, has shown that markets will probably be created if the production of goods can be increased. Swaziland possesses adequate export markets and it is assumed that these markets will increase as production increases.

The references used in this section are 2 and 38, as listed in Section T.

SECTION B

POPULATION

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SECTION B
POPULATION

EXISTING POPULATION

The resident population of Swaziland was about 480,000 according to the 1976 Swaziland Population Census. The absentee population was about 31,000, bringing the total population to about 511,000. The absentee population is mainly composed of males who have taken up temporary residence in the Republic of South Africa (RSA) to work. Because this report is concerned with water use and consumption in Swaziland and because worker emigration projections are unknown, the absentee population is not considered further in this section.

The population in recent years has been increasing at a rate of 3.36 percent per year. Using this rate of increase, the 1980 population is estimated to be about 548,000, and population size would double about every 21 years. This fairly high growth rate is the result of a fertility rate which has remained fairly constant at 6.87 births per woman and a declining mortality rate which is due to improved health care programs and facilities.

The country is divided into four governmental districts for administrative purposes. These districts are shown in figure B-1. Originally, the four districts were established with roughly equal populations; however, migration to the urban areas has caused a noticeable shift in the district populations. The estimated 1980 population for these districts is presented in table B-1.

Figure B-1
Swaziland Districts

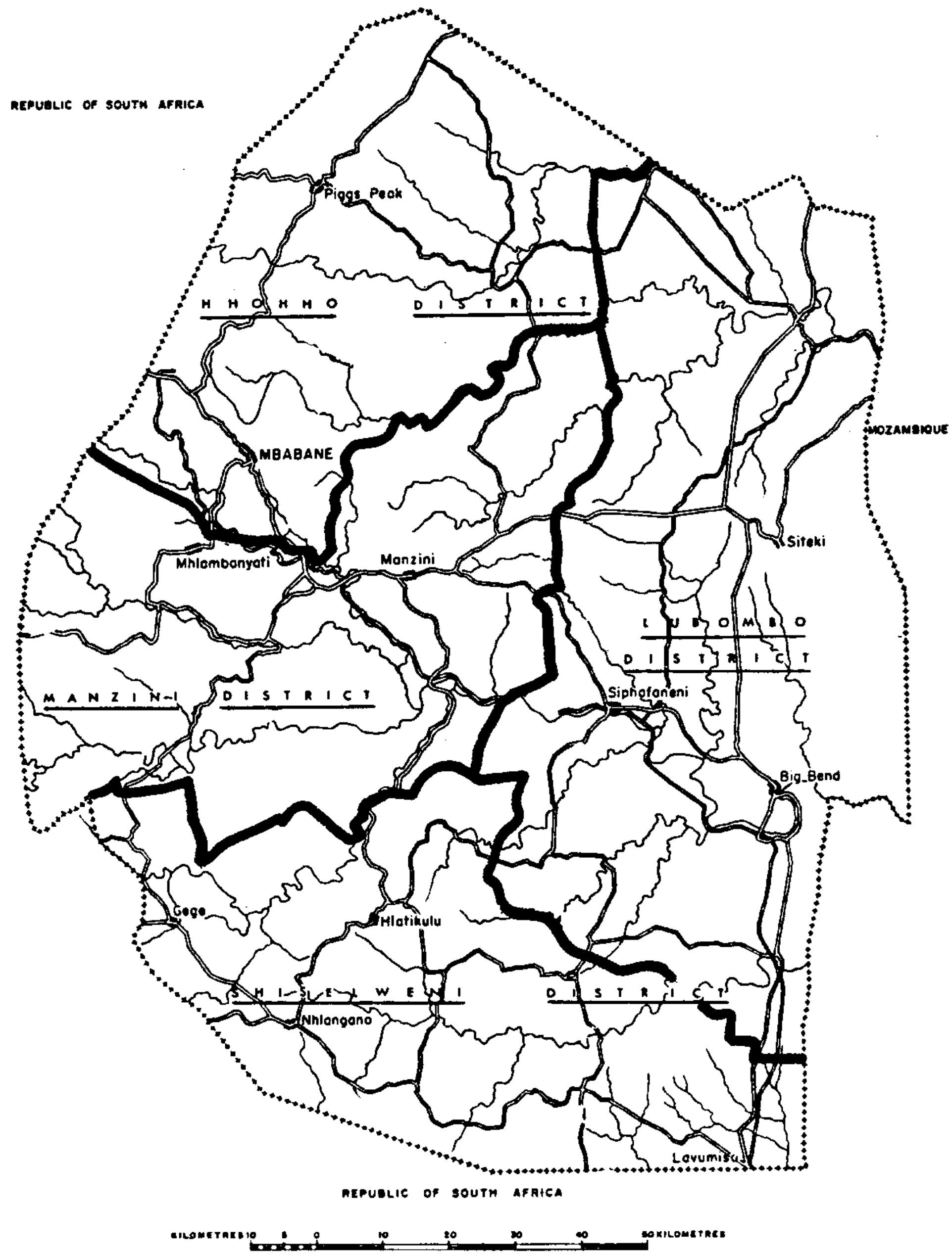

Table B-1
District Population
1980

District	Population
Hhohho	148,000
Manzini	157,000
Shiselweni	128,000
Lubombo	115,000
Total	548,000

Source: Office of Economic Planning

The largest population cluster in the country is the Mbabane-Manzini urban corridor; this corridor is the center of government, education, commerce, and industry. The urban corridor is located on the border between the Hhohho and Manzini districts and accounts for the population size difference in the four districts. This population difference is expected to become more pronounced as young Swazis migrate to the urban areas and as the growth of government continues. The population in the Mbabane-Manzini urban corridor increased by about 60 percent between 1966 and 1976. Nearly all other urban areas are small clusters located around centers of economic activity, such as sugar mills and pulp or timber mills. For purposes of this report, the population of each drainage basin was determined by using the census enumeration areas map overlayed by the drainage basin map. Drainage basin populations are presented in table B-2.

The Mbabane-Manzini urban corridor is located in the Little Usutu basin and contains about 70 percent of the nation's urban population. The remaining 15 urban areas range in size from less than 1,000 to 5,000 people. The rural population is located on small farm plots scattered throughout each drainage basin.

Table B-2
Drainage Basin Population
1976

Drainage Basin	Rural	Urban	Total
Lomati	19,000	0	19,000
Komati	40,000	7,000	47,000
Mbuluzi	44,000	7,000	51,000
Little Usutu	42,000	58,000	100,000
Great Usutu	113,000	8,000	121,000
Ngwempisi	23,000	0	23,000
Mkondo	26,000	1,000	27,000
Ngwavuma	48,000	0	48,000
Pongola1/	33,000	3,000	36,000
Tembe2/	7,000	1,000	8,000
Total	395,000	85,000	480,000

1/ The Pongola basin is located in southern Swaziland and drains into the RSA.

2/ The Tembe basin is located in the Lebombo region and drains into Mozambique.

Source: 1976 Swaziland Population Census

POPULATION PROJECTIONS

The Office of Economic Planning has prepared three sets of population projections--low, medium, and high. These projections were made for each year from 1976 to 1986 and for the years 1990, 1995, and 2000. They were based on the assumptions outlined below.

LOW PROJECTION

The low projection was made assuming that both the fertility and mortality rates would decrease and the life expectancy would increase

by about 18 percent for females and 16 percent for males by the year 2000. It was assumed that the fertility rate would decrease by 35 percent by the year 2000.

MEDIUM PROJECTION

The medium projection was made assuming that both fertility and mortality rates would remain constant at the estimated 1976 levels.

HIGH PROJECTION

For the high projection, it was assumed that the fertility rate would remain constant at the 1966 to 1976 level and that the mortality rate would continue to decline at the 1966 to 1976 rate.

The Swazi government projections were used to make projections for the years 1985, 2000, and 2030 for this report. Projections for 1985 and 2000 were extracted directly from the growth curve. Projections for 2030 were derived from approximate straight-line extensions of the growth curve. These projections are presented in table B-3 for each of the 10 drainage basins.

The high projection shown for the year 2000 represents a continuation of the present population growth rate. At this rate of growth, the 1976 population of Swaziland would double before the turn of this century and would double again within the planning time frame used in this report. It is doubtful that such a high rate of growth could be sustained for this long; it is assumed that other population-limiting factors would begin to take effect before these population figures are realized.

Table B-3
Population Projections
(1,000's)

Drainage Basin	Base (1976)	Low			Medium			High		
		1985	2000	2030	1985	2000	2030	1985	2000	2030
Lomati	19.0	24.0	31.6	40.5	24.4	34.9	49.8	24.6	36.9	59.0
Komati	47.0	60.1	79.9	103.5	61.0	88.4	127.3	61.5	93.4	150.8
Mbuluzi	51.0	70.8	113.3	213.0	71.9	125.4	262.0	72.5	132.5	310.3
Little Usutu	100.0	142.9	235.9	465.0	145.0	261.0	572.0	146.3	275.8	677.4
Great Usutu	121.0	158.1	228.5	354.0	160.4	252.8	435.4	161.9	267.2	515.7
Ngwempisi	23.0	30.4	43.7	67.5	30.8	48.3	83.0	31.1	51.0	98.3
Mkondo	27.0	32.9	43.7	57.0	33.4	48.3	70.1	33.7	51.0	83.0
Ngwavuma	48.0	59.5	78.9	102.0	60.3	87.3	125.5	60.9	92.3	148.6
Pongola	36.0	43.6	57.6	75.0	44.3	63.7	92.3	44.7	67.3	109.3
Tembe	8.0	10.1	15.8	24.0	10.3	17.5	29.5	10.4	18.5	35.0
Total	480.0	632.4	928.9	1,501.5	641.8	1,027.6	1,846.9	647.6	1,085.9	2,187.4

Source: Office of Economic Planning

While the low projection contains a relatively high rate of growth, it represents a more realistic view of the growth that could be sustained. The government's population program should attempt to bring the growth rate of the country down to this level or lower. At this rate of growth, the population of Swaziland would not double until after the turn of this century.

The references used in this section are 28 and 43, as listed in Section T.

SECTION C

SOIL CONSERVATION AND LAND MANAGEMENT

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SECTION C
SOIL CONSERVATION AND LAND MANAGEMENT

As stated in Swaziland's Third National Development Plan, the number one objective in agricultural development is ". . . to protect and enhance the quality of the natural environment." The intention, specifically, is to preserve the nation's soils, which are proclaimed to be the nation's most valuable resource. The high value placed on soils results largely from the imminent danger of their being permanently lost.

"The most significant environmental problem facing Swaziland today is the deterioration of arable and communal grazing land in the traditional sector." Abuse of the land is an immediate concern and is caused mainly by the traditional livestock husbandry practices used by Swazis on Swazi Nation Land (SNL) or on any Freehold Title Land (FTL) that they occupy.

CULTIVATED LAND

Although the role of cultivation has been deemed significant in contributing to soil erosion, it is minor when compared to the role of livestock grazing. Swazi farmers on SNL generally till the soil by hand or with draft teams and grow subsistence crops almost exclusively. Usually the area cultivated is no larger than is considered necessary for subsistence purposes; therefore, only about 12 percent of the land is devoted to crops. Contour grass strips, promoted through the 1940's

and 1950's and mandated by the King, are widely used and are effective in erosion control. Similar regulations regarding contour plowing and protection of streambanks have also contributed to checking erosion on SNL fields.

Despite these moderating factors, some erosion continues to occur on SNL fields. Some waterways are badly aligned, promoting gully formation, and most major crops are clean tilled, depriving the fields of cover. Also, as population pressure grows, steep slopes of from 3 to 12 percent or more are increasingly being cultivated. Without proper land management, this permits severe sheet and gully erosion of the thin soils.

On FTL, most of the land area is composed of large estates; these estates are generally owned by non-Swazis but some are owned by Swazis. On these estates, agricultural production is centered on the irrigation of commercial crops for export. On FTL, smaller farms outnumber these large estates but still occupy only a small part of the FTL land area. Significant field erosion on FTL-cultivated lands was not reported in the literature available for this report.

The erosion that does occur on arable land is being addressed on several fronts, most notably through the Rural Development Area (RDA) Program of the Ministry of Agriculture and Cooperatives, which covers SNL. The RDA Program is designed to advance environmental conservation of soils, rangeland, and woodland, as well as to improve rural living standards and provide social services and infrastructure. In RDA's, arable land is delineated from pastureland and is located on suitable slopes; grazing land is allocated for steeper slopes with thinner, less valuable soils. Reclamation and protection works are employed; these include terraces on steep slopes, grass strips on gentler slopes, and alignment of waterways, roads, and housing areas along slope contours.

Eventually all of SNL is intended to fall under the RDA Program, which will allocate about 27 percent of SNL acreage to cropland. Inputs such as seed, fertilizer, and irrigation may tend to actually decrease the area under cultivation because the Swazi farmer will need less cropland to meet his subsistence needs. Therefore, productivity has fallen disappointingly short of goals on existing RDA's.

RDA's have, however, involved the nation's greatest advances in infrastructure development. Also, the social and environmental contributions that have been made are claimed to be sufficient justification for the program without economic gains. Therefore, the RDA Program, although under review, will probably continue in some form for a number of years.

GRAZING LAND

THE EROSION PROBLEM

The modern livestock husbandry practiced on large FTL estates has played a minor role in causing the soil erosion problem. The 100,000 cattle on these farms and estates are raised strictly for commercial purposes. Rather than quantity, the quality of animals is held foremost; only upgraded or exotic stock are kept. Carrying capacities are boosted through management practices such as bush clearing and pasture management and improvement. Stocking rates are kept well below the land's carrying capacity and relatively little overgrazing occurs.

The erosion problems that do arise probably occur on lands held by absentee owners. These lands may fall into traditional grazing use by

neighboring Swazis and may begin to suffer from overgrazing and bush encroachment.

Also, the small FTL farms which have less intensive or more traditional management practices can experience the serious overstocking and overgrazing that is described in the following paragraphs concerning SNL.

TRADITIONAL SWAZI PRACTICES

The leading cause of Swaziland's erosion problem is the overgrazing of SNL by Swazi traditional herds. The Swazi people, traditionally pastoralists, place a high value on cattle, and about 87 percent of SNL is used as communal grazing land. About 27,000 farmers, or 60 percent of all SNL farmers, own cattle. The average herd size is 19 head. Swazis prize cattle number, rather than cattle quality, as a measure of their personal wealth, status, and security.

The value placed on cattle is reasonable in the sense that cattle are a self-maintaining store of resources, making use of land that historically has offered little other apparent sustenance. Cattle graze cost-free on communal land; reproduce themselves; are mobile; supply meat, milk, and materials; and can draw a plow. They are used for lobolo, the bride price; are tax-free; and are a good investment and hedge against inflation. They are sold to meet immediate cash needs but not for surplus cash. The Nguni varieties have become fairly well adapted to local conditions.

Under traditional Swazi law and custom, grazing land is communally owned and its privatization is forbidden. Thus, there is little individual responsibility for the land's upkeep, and the herder's interest continues to lie in maximization of his herd size.

Traditional husbandry aggravates the land deterioration. There is little culling of the herd for upgrading, and little or no attention is

paid to fencing, pasture rotation, or any other pasture management. Fires are set to encourage new green growth, exposing soil to erosion; however, these fires may also serve to hinder bush encroachment. The cattle are driven over the ground to and from the kraal nightly, are milked daily, and are provided no supplements to the veld grasses.

Disincentives to destocking are maintained by the traditional land tenure system, by which the King holds all SNL in trust for the Swazi Nation, and the farmer can own none of the SNL. Farmers are, therefore, disinclined to invest in land or houses which could serve as alternative investments to cattle. They also cannot offer land as collateral for credit. The collateral they can offer is cattle, this being yet another incentive for owning large herds.

Herd harvest rates are less than 10 percent, compared to the 14 percent offtake of commercial ranches. Since cattle are valued more than currency, they are primarily sold only to meet immediate cash needs such as school fees. Even these sales for cash needs may be further reduced as cash becomes increasingly available from cash crops, wage incomes, and higher per cow sales prices. Commercialization is encouraged through government sales yards, fattening ranches, and breeding ranches; the Swazi, however, prefers to barter directly with the local butcher or other buyer at the regular cattle dipping.

OVERSTOCKING AND ITS RESULTS

In the past generation, the emphasis on stock numbers has severely stressed range resources. As population demands for cropland have increased, available rangeland has decreased. Denudation, sheet erosion, gully formation, and bush encroachment have decreased the land's potential. The soil is trampled, rain infiltration is reduced, dams are silting in, and springs are not recharged. The impacts are seen especially on higher slopes and in southern regions but are felt throughout SNL.

Under all the pressure of overgrazing, the Swazi national herd displays low calving rates (below 50 percent), high mortality rates (4 to 10 percent), and slow growth to maturity. The herds suffer malnutrition at critical seasons and show low productivity generally. Yet, despite this, the Swazi herds grew at an average 1.9-percent annual rate from 1970 to 1975. And, forthcoming veterinary and husbandry changes promise to increase herd growth rates even more. Livestock populations are shown in table C-1.

The current nationwide average stocking rate is estimated to be 36 animal units per square kilometer (0.36 stock units per hectare). This is the highest in Africa and far exceeds the land's carrying capacity. Current stocking rates on SNL and the recommended optimum rates are shown in table C-2.

The result of this stocking rate is that Swaziland is losing soil at an estimated rate of from 25 to 35 tons per hectare per year against an estimated maximum tolerable rate of 3 tons per hectare per year. In other terms, in an average 10-year period, Swaziland loses soil that would require about 1,000 years to form.

Government projections of soil life expectancies are given in table C-3.

It is estimated that, at present grazing rates, 20 percent of SNL soils will be irretrievably destroyed within 25 years. And, this estimate does not allow for the increase in grazing intensities now underway.

PROGRAMS ADDRESSING THE PROBLEM

In addressing the national overgrazing problem, the government has planned a number of steps to reduce overstocking. These can broadly be classified into the two categories of destocking and pasture improvement.

Table C-1
Livestock Population in Recent Years
(1,000's)

Livestock	1960	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Total Cattle	521	568	572	589	602	607	622	634	634	645	660
Swazi 1/	402	460	468	486	499	510	526	-	546	507	513
Other 1/	119	108	104	103	103	97	96	-	88	138	147
Goats	-	-	262	252	265	249	263	270 2/	256	257	284
Sheep	-	-	43	37	38	30	35		31	30	29

1/ These figures distinguish between Swazi-owned and other-owned cattle through 1975 and between SNL and FTL cattle from 1977 through 1979.

2/ This figure is the combined population of both goats and sheep.

Sources: World Bank, 1977, and Swaziland Ministry of Agriculture (MOA)

Table C-2
Current and Recommended Stocking Rates on SNL
(animal units per hectare)1/

Region	Current	Optimum
Highveld	0.51	0.38
Middleveld	0.75	0.38
Lowveld	0.48	0.25 2/
Average	0.55-0.62	0.29-0.40

1/ Conversion from hectares (ha) per animal unit to animal units per hectare was made in this report.

2/ The optimum rate here is lower because of lower rainfall, rapid bush encroachment, and lack of fodder crops.

Sources: Library of Congress, 1980, and World Bank, 1977

Table C-3
Life Expectancy of Swaziland Soils
Under Current Grazing Intensities

Estimated Grazing Intensity (animal units/ha)1/	Area in Swaziland (ha)	Life Expectancy of soils (years)
1.3-2.0	16,790	5
1.0-1.3	55,200	5-15
0.80-1.00	65,280	10-15
0.67-0.80	91,600	15-25
0.50-0.67	79,355	25-30
0.40-0.50	256,190	50-100
under-0.40	690,165	over 100

1/ Conversion from hectares per animal unit to animal units per hectare was made in this report.

Source: Spargaaren, W., 1977, in an unpublished MOA map referenced in Roder, 1977

DESTOCKING

The RDA Program addresses destocking as the number one priority in land management and as a prerequisite to success in pasture management or herd management. While this priority has been recognized for years, significant improvements have yet to be achieved.

The primary emphasis by the government in seeking lower herd numbers has been to develop an economically viable cattle industry which would promote raising cattle for their individual productivity rather than their abundance. Through the RDA Program and extension activities, herders are encouraged to produce and harvest more meat for sale and to increase dairy product consumption and sales.

Upgrading of herd animals is promoted through establishment of bullcamps or breeding ranches, where exotic bulls are provided. Culling of poorer and younger animals is recommended. Supplemental feeding is encouraged and stock dams are being built. Mandatory weekly or biweekly dipping has been in effect for years. Dairy farmers are allowed to spray rather than dip their animals, allowing milk production even on dipping days. Improved dip chemicals are being sought, and veterinary services are likely to continue to improve. Another possible effect of the RDA Program is that tractor pools will reduce the need for the draft animals which comprise 17 percent of the herd.

In the marketing aspect of this campaign, the government encourages herders to send cattle to fattening ranches for fattening and/or sale. Cattle trucks are provided. Public and private sale yards have been established around the country, and the Swazi Meat Corporation serves as a buyer of last resort at a floor price of E68.00 per head. The reluctance of Swazi herders to commercialize has been noted.

PASTURE IMPROVEMENT

Increasing the productivity of grassland available to cattle is considered a more positive, if less urgent, objective than destocking.

Pasture management is promoted on RDA's by delineating pasture from cropland, fencing pasture perimeters, and then establishing paddocks and rotational grazing. Greenbelts of improved pasture, serving as physical and management buffers between grazing land and fields, have met with some success. Bush clearance increases the pasture area available, and experiments are underway to evaluate plantings of vigorous legumes for controlling bush encroachment. Gully reclamation is being pursued while studies seek to find nutritious new grass species and simple means of seeding denuded pastures. Occasionally, land has been purchased to establish community ranches and increase the pasture available to the cattle. Supplementation of the normal diet with industrial byproducts and field-grown forages is planned.

The World Bank report projected that rotational grazing and pasture improvement would increase carrying capacity only marginally, about 10 percent in 10 years. No amount of pasture improvement can accommodate a livestock population which is allowed to continue to grow without control. Destocking would appear to be the overriding priority, whether by facilitating commercial developments or by less economically and politically attractive means.

IMPLICATIONS OF WATER DEVELOPMENTS FOR SOIL CONSERVATION

Management of the soil resource could be affected by development of irrigation on cropland or on pastures. Irrigation of crops will offer major potential influences in soil conservation practices. Primarily positive long-term effects would occur with development of the confidence of Swazis in crop income and a coinciding decline in the emphasis on cattle herd size maximization. Negative impacts would

include a short-term decline in cattle sales as crop incomes are boosted.

Pasture irrigation will also influence soil conservation trends. Initial boosts in carrying capacity might be matched in the near term by the reproduction and intentional buildup of herds. In the long term, however, pasture irrigation would facilitate commercial operations which would allow destocking. These possible effects will be discussed in the following paragraphs.

EFFECTS OF IRRIGATING CROPLAND

One significant impact of crop irrigation would be an increase in crop productivity. In the near term, this productivity could encourage cattle herd increases because irrigation facilitates cash cropping and may provide surplus subsistence foods. The extra cash raised from selling such crops could substitute for the cash that would otherwise have to be raised by cattle sales. Cattle sales would decline and the extra cash could, in fact, be used to buy more cattle. This trend is apparent today in some areas but may subside as appreciation of cash surpluses grow.

The long-term prospect for crop irrigation is that it may provide farmers with confidence in farming and a sense of security that could substitute for their traditional dependence on cattle. Reduced stocking rates could result. Although more a theory than a practice at this time, this effect is an integral part of government economic and social objectives. The rationale or mechanism is described in the following paragraphs.

First, as mentioned earlier, irrigation would facilitate cash cropping and crop surpluses. Yields would be more consistent and a farmer's crop income would be relatively steady. Part of the attraction of wage employment over farming lies in its dependability and its

security. This differential would be reduced as irrigated farming appears to be a less risky alternative career. Also, irrigated crops could prove to be more dependable in hard times than livestock. The greater security of farming would then appear preferable to the more risky alternative of cattle, and cattle would lose their priority as a source of wealth.

Further, not only the predictability but also the profitability of irrigated crops would improve their status relative to cattle. Efficient beef ranching is said to return a profit per hectare which is one-half the return from maize and 1/20 to 1/50 the return from cash crops. Where cattle are in conflict with irrigable land (for our purposes) or any good arable land, this difference would be appreciated by the Swazi farmer. Again, the popularity of wage employment can be cited as evidence of the Swazi appreciation of cash income. The practices of saving and investment would also continue to gain popularity.

It has already been noted that these intended impacts from irrigation have not been realized in some ongoing RDA's. This will not necessarily always be the case. It is fair to consider it very probable that, in time, Swazis will come to appreciate and exploit the potential of irrigated land. Cattle will be expected to continue serving an important economic and social purpose. But herd maximization may no longer be considered the best land use. Lastly, it could be said that without crop irrigation, the chances of providing rural Swazis with an alternative to herd maximization are significantly reduced.

The final reference to crop irrigation on SNL concerns forage crops. Any increase in these crops, facilitated by irrigation, would relieve some pressure from grazing land. That relief potential, however, would appear to be very small.

On FTL, the increased availability of irrigation would probably affect land use patterns by encouraging the conversion of areas under pasture into irrigated cropland. Because cultivation accounts for more erosion than does grazing on FTL, erosion rates would tend to rise. The degree of increase on FTL, however, could be minimal because of the gentle slopes typically being farmed.

Also, the conversion of any FTL pasture to irrigated cropland would tend to increase grazing pressure on the remaining pastures. Again, this increase could be nominal, considering the amount of FTL apparently "underused" and available for either cropping or grazing.

EFFECTS OF IRRIGATING PASTURES

The probable effects of pasture irrigation on Swaziland's soil erosion problem appear mixed in the short term but positive in the long term. Irrigation water could be used to water either native or tame pastures used for grazing or for hay harvesting. This could boost pasture carrying capacity and, therefore, reduce overgrazing. It would also facilitate development of commercial dairying, beef production, or a variety of operations. The government expects that commercial operations will lead to a deemphasis of livestock numbers while promoting livestock quality. It is a well-known fact, however, that as long as traditional Swazi incentives and herding practices continue, an increased carrying capacity would serve as an incentive to increase herd sizes.

Further, improved pasture would enhance herd health, spontaneously increasing the calving rate and reducing the mortality rate. Therefore, harvest rates would have to increase proportionately in order to prevent the stimulated herd growth from quickly overtaking the new carrying capacity.

Finally, it should be noted that promotion of commercial cattle production offers mixed blessings. It may indeed reduce the overall cattle population and reduce erosion. However, commercial cattle raising, as practiced in developed countries, is very land intensive.

Commercial beef production in the United States relies heavily on fattening by supplemental feeding with maize, soybeans, and alfalfa (lucerne). Eating beef which has been fed maize or soybeans provides people with only 10 percent of the food provided by eating the maize or soybeans directly. This is because 90 percent of any food fed to cattle is lost as feces and other wastes; therefore, land capable of producing crops for human consumption should not be used for cattle grazing. Cattle are most efficiently fed by grazing on marginal lands which could not produce a crop for people.

Food shortages in various countries are often the result of government policy not of poor land productivity. Swaziland does not have a serious protein shortage and can expect to meet protein needs without the luxury of high beef consumption. Developed countries are now rediscovering this ability; for example, beef production has been declining in the United States.

The references used in this section are 23, 24, 26, 31, 37, 39, 40, 42, 51, 52, 54, 73, and 76, as listed in Section T.

SECTION D

DOMESTIC WATER SUPPLY AND WATER-RELATED DISEASE CONSIDERATIONS

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SECTION D

DOMESTIC WATER SUPPLY AND WATER-RELATED DISEASE CONSIDERATIONS

HEALTH OVERVIEW

Swaziland is a developing country that enjoys reasonable literacy rates and infrastructure and has not yet been documented as having serious nutritional problems. Additionally, it had an average per capita Gross Domestic Product (GDP) of more than E445 in Fiscal Year 1976-1977, ranking it as a Lower Middle Income Country (LMIC).

Real income among the majority of people, however, does not favor health maintenance. About 80 percent of the population is rural. Up to 73 percent of Swazi Nation Land (SNL) rural residents and 40 percent of urban squatters, or about 52 percent of all Swazis, earn less than E150 per year. Furthermore, most homesteads draw their water supply from streams or ponds and a large percentage of homes have to carry water more than 1 kilometer (km). Their water supply, thus, is untreated and not abundant.

These factors of poverty and poor water supply contribute to the fact that Swaziland has health statistics significantly worse than even the average Low Income Country (LIC). Table D-1 presents a comparison of health statistics.

Table D-1
Comparison of Three Health Statistics
in Swaziland and Other Countries

Parameter	Average LMIC	Average LIC	Swaziland
Physical Quality of Life Index (out of 100)	59	49	36
Life Expectancy (years)	61	48	46.5
Infant Mortality (deaths per 1,000 live births, before age 1)	70	134	156

Sources: U.S. Agency for International Development (USAID), 1979, and 1976 Swaziland Population Census

Many factors account for these unfortunate health figures; some of these factors are as follows:

- mother-child health problems, which result in low resistance to communicable diseases;

- incomplete implementation of available immunization techniques;

- social transition and resulting emotional and social diseases; and

- a high prevalence of water/sanitation-related diseases.

Swaziland has sufficient water to meet its domestic needs. Most of the population, however, drink water taken from streams or ponds and bathe and wash clothes in those same waters. Those streams and ponds can and do harbor numerous agents of disease; further, cattle and people commonly pollute those waters with excreta. Additionally, poor access to water promotes minimal hygiene practices at home and burdens women who must collect the water.

Water-related diseases figure highly in the population health status. Gastroenteritis and dysenteries are major child mortality factors for children ages 4 weeks to 2 years. Schistosomiasis (bilharzia) is a major debilitating disease and is increasing with irrigation development. Typhoid is endemic in parts of the country. Malaria has a recently demonstrated potential to reach epidemic proportions. And, more than 25 other water-related human and livestock diseases occur in the country. This report will deal primarily with schistosomiasis because of its close relationship to irrigation. But a broader approach to control of these diseases, through provision of adequate safe domestic water, is probably the only realistic approach.

SCHISTOSOMIASIS

LIFE CYCLE AND TRANSMISSION

There are two forms of schistosomiasis in Swaziland: urinary and intestinal, the latter being somewhat more serious but less common. Schistosomiasis is a parasitic disease caused by helminth worms called schistosomes. Man is the primary host, while several species of snails serve as the secondary hosts required in the schistosome life cycle. Schistosome larvae which leave the snail host and swim in the water can penetrate any human skin. They migrate through a person's heart and lungs to the liver; there, they mature and mate and inflict most of their damage.

They later migrate to near the bladder (urinary) or intestine (intestinal), into which organ the female's eggs are laid over a 1-to-2-year period. The eggs pass out with the excreta. If they reach

water, the eggs form larvae which can attack snails, and this completes the cycle.

Transmission of the disease to humans is optimal at certain times of the year and of the day. Table D-2 presents the schistosomiasis transmission rates.

Table D-2
Schistosomiasis Transmission Rates

Times	Urinary Form	Intestinal Form
Spring	Low	Low
Summer	Peak, November to March	Peak, October to January
Autumn	Low	Low
Winter	Almost nil	Almost nil
Daytime	Peak, 1000 to 1400 hours	Peak, 0800 to 1400 hours

Source: USAID, 1979

PREVALENCE

Schistosomiasis is estimated, by some inexact but indicative surveys, to occur in about 30 percent of the total population. Government of Swaziland (GOS) school health teams, using data from 1971 to 1978, reported a 36-percent prevalence of the urinary form and a 26-percent prevalence of the intestinal form. School children were sampled because the urinary form (but not necessarily the intestinal form) peaks in teenagers.

Within the statistical averages, there are great variations according to age, sex, habits, and environment. Boys may show a higher prevalence because they swim in streams more than girls; they also have more

of a tendency to urinate in streams. The American Public Health Association study in Swaziland revealed that the prevalence increased with age, as shown below.

	Age			
	Preschool	8 years	12 years	Older
Prevalence, in percent	4	11	22	Either lower or higher

Source: Roder, 1977

Geographical location is also a primary factor. The Highveld region has a significant but relatively low prevalence. The fast streams hinder snail establishment, and cool temperatures hinder schistosome larvae development within the snails. The Middleveld and Lowveld regions provide more ideal conditions for snails and schistosomes, and populations in those regions have 60- to 90-percent prevalence rates.

In the Middleveld region, snail hosts for urinary schistosomes are widespread. Snail hosts for intestinal schistosomes also occur and are increasing with the number of artificial water bodies. In the Lowveld region, snail hosts for both forms of the disease occur extensively.

Another primary factor is proximity to irrigation because the associated reservoirs and canals provide snail habitat. Table D-3 shows the distribution of schistosomiasis prevalence according to a USAID and World Health Organization (WHO) 1976 study. The data are from about 20 of more than 400 primary schools in Swaziland.

Table D-3
Schistosomiasis Prevalence in
Irrigated and Unirrigated Areas

Location	Urinary (percent)	Intestinal (percent considered underreported)
Highveld	10	1
Middleveld-Irrigated	75	30-75
-Other	25-50	10
Lowveld-Irrigated	25-50	75
-Other	25	25
Lebombo Plateau	25	25

Source: Roder, 1979

Another study among the infant to 15-year age group showed a 38-percent prevalence for those living away from irrigation projects, a 62-percent prevalence near uncontrolled projects, and an 18-percent prevalence near projects with snail controls. This indicates both the threat and potential of irrigation development. Effective control, however, is still lacking. Despite snail control on some of the irrigated acres, schistosomiasis has increased with irrigation.

Still another factor may be the river basin in which a person lives. This is indicated by the data presented in tables D-4 and D-5.

WATER SUPPLY PROGRAMS

CURRENT

The USAID has stated that the three most critical missing elements in current water-related disease control efforts are health education, sanitary waste disposal, and special schistosomiasis interventions. Schistosomiasis interventions must include the provision of adequate safe water as the foremost priority, as well as the broad approach being pursued for control of both water-related diseases and other diseases.

Table D-4
Prevalence of Urinary Schistosomiasis by Topographical Zones and River Basins, Children Ages 5-14 Years

Zone	River Basin	Prevalence (average percent)	Number Examined
Middleveld	Lomati	62.1	449
	Mbuluzi	63.1	536
	Usutu (including Manzini)	37.7	4,747
	Overall	42.0	5,732
Lowveld	Mbuluzi	36.6	639
	Usutu (including Big Bend Bhuli)	37.8	1,454
	Ngwavuma	11.3	1,109
	Overall	28.4	3,212

Table D-5
Prevalence of Intestinal Schistosomiasis by Topographical Zones and River Basins, Children Ages 5-14 Years

Zone	River Basin	Prevalence (average percent)	Number Examined
Middleveld	Lomati	71.6	268
	Mbuluzi	63.3	347
	Usutu (including Manzini)	3.2	647
	Overall	18.6	1,262
Lowveld	Mbuluzi	20.8	48
	Usutu (including Big Bend Bhuli)	28.3	1,480
	Ngwavuma	17.2	436
	Overall	25.6	1,964

Source: Jobin and Jones, 1976

It is estimated that 37 percent of the population received minimal piped water in 1980. This included 75 to 80 percent of the urban population and 20 to 30 percent of the rural population. About 60 percent of the total population has no access to piped water.

The provision of safe water to rural and low-income urban homes is being addressed by several programs.

- The Ministry of Health (MOH) is conducting spring protection. The MOH develops up to 45 springs annually which serve an undetermined number of people. A clean water supply is the MOH's primary concern in this field.

- The Rural Water Supply Board (RWSB) of the Ministry of Works has provided piped water in about 33 systems serving about 26,000 people. This program preferably develops gravity-feed systems without onstream storage and alternatively develops boreholes or pumps. It is currently building at a rate of about 12 to 16 new systems annually.

- A joint United Nations Environmental Program/World Health Organization/United Nations Children's Fund (UNEP/WHO/UNICEF) pilot program is developing boreholes and other systems to deliver piped water directly to more than 500 homesteads in a pilot area.

- The Rural Development Area (RDA) Program of the Ministry of Agriculture (MOA) has so far developed about 27 water supply systems which serve about 4,500 people. The RDA Program places priority on springs for potable water, separate from streams and reservoirs. Reservoirs of 10 to 12 hectares (ha) are planned at each RDA for irrigation and nonconsumptive domestic uses.

• Health education is also being addressed by GOS ministries aided by donor agencies. The rural clinic system is considered nominally sufficient in scale; it provides one infrastructure through which health education personnel can operate. However, personnel are still insufficient in number and in training, and logistical support could be better. Also, 55 to 65 percent of the facilities and staff are in the Mbabane-Manzini corridor and, thus, are most accessible to that 16 percent of the population.

FUTURE

The USAID considers current rural water supply projects to be progressing at a reasonable rate. They are being conducted by the GOS with aid from Britain, Canada, the United Nations, and the African Development Bank. Future prospects are:

• The MOH is expected to continue protecting up to 45 springs annually.

• The RWSB has targeted 34 additional communities for water supply completion over the next 3 years. This program plans to have reached 170,000 people by 1985.

• The UNEP/WHO/UNICEF program was designed as a pilot project which will be suspended after completion of the current phase.

• The RDA Program plans to reach up to 5,000 people annually. However, it is currently undergoing review.

• The MOH's water supply program and health education programs will be supplemented by a forthcoming Rural Water Borne Disease Project. This project, assisted by the USAID, will include health education, demonstration latrines, and a 3-year epidemiological survey of schistosomiasis prevalence.

By 1985, these programs may reach 50 percent of the population. A goal is to provide virtually the entire population with improved water supplies by 1990. These programs might be expected to encounter various difficulties that will prevent achievement of such goals unless government resolve remains solid. Rural domestic water demand projections in the Water Use and Consumption Section of this report have assumed that, even in the best conditions, 50 percent of the population would not be served until the year 2000 and 100 percent would not be served before the year 2030.

EFFECTS

The advantage of all these programs is, of course, that they may provide adequate safe drinking water and other domestic water to the populace. A disadvantage is that some of these programs, with their associated programs, especially irrigation, will probably increase schistosomiasis prevalence in the near term. If uncontaminated water is the source and if irrigation is not developed, this disadvantage will not materialize.

The planned irrigation reservoirs, stock-watering ponds, fish ponds, and other structures will expand the habitat available to secondary host snails. Snail hosts for the more serious intestinal form of schistosomiasis appear to be several times more abundant in dams than in streams. Dams and other water impoundments, therefore, may lead to a notable increase in the prevalence of intestinal schistosomiasis. The use of boreholes, protected springs, and elevated concrete reservoirs would not expand snail habitat.

Further, any irrigation, whether public or commercial, will expand snail habitat in the form of reservoirs, canals, and ditches. The RDA Program alone plans to build 85 separate dams and reservoirs and 72 km of small canals and ditches. Initially, schistosomiasis would probably

increase from 25 to 50 percent in irrigation areas. The greatest possible impact would be in the Middleveld region, where most maximum-input RDA's are planned. The other main impact area would be the Lowveld region, where plantation-scale irrigation is a possibility.

If adequate control measures can be developed, this disease may be reduced over the long term. Some types of water resource development will assist in this control, while other types of development will not. The main contribution of any water development to control this and other diseases would be the provision of abundant potable water.

SCHISTOSOMIASIS CONTROL MEASURES AVAILABLE FOR CONSIDERATION

The main methods available for control of schistosomiasis are described below.

DIAGNOSIS AND TREATMENT OF THE DISEASE IN THE POPULATION

Health personnel can be trained to recognize this disease and/or surveys of the populace can be made. Chemical curative treatment is very effective, and new drugs lack the significant side effects of earlier drugs.

Health education is a vital part of this approach to diagnosis and treatment of schistosomiasis; it promotes disease awareness and hygienic habits which can prevent reinfection. It does very little good to treat this disease in the population if people continue nonhygienic behavior patterns. Any successful control efforts must incorporate population education.

KILLING OF SNAILS

This is commonly done with molluscicidal chemicals, of which at least two have been used in Swaziland with some effectiveness.

Some of the following biological controls are also possible. Plants toxic to molluscs do grow in some of the country's waters. Animals known to prey upon the host snails include various fish, ducks, egrets, turtles, rodents, snakes, sciomyzid flies, and water beetles. Organisms which could serve as antagonists of human schistosomes within snails include nonhuman trematodes (e.g., echinostomes) and bird schistosomes. An introduction of nonhost snails as competitors could reduce host snail populations. Also, clearing plants from water bodies removes snail food and habitat.

PROVISION OF SAFE WATER

Programs to provide safe water would eliminate ingestion of or contact with infested waters. Numerous possible methods are available for water supply programs.

IMPROVEMENT OF SANITATION

Improving sanitary facilities would prevent indiscriminate elimination of human or animal wastes in or near water bodies, thereby preventing infected persons or cattle from returning parasite eggs to the water bodies. Excretion into water also fertilizes the water, enhancing the habitat for snails. Fencing is considered the only sure solution here, although health education and latrine facilities also have an obvious role.

STRUCTURAL DESIGN

Reservoirs, canals, and other structures can be designed for control of snail populations and transmission. Examples are concrete lining and covering of canals, steep canal gradients to achieve flows of from 0.65 to 0.80 meters per second, siphon spillways or other means for reservoir drawdown to expose shoreline snail habitats, fencing of reservoirs, and efficient drainage designs.

PROSPECTS FOR CONTROL MEASURES

The potential and problems of these control measures in Swaziland are described below.

DIAGNOSIS AND TREATMENT OF THE DISEASE

The diagnosis and treatment of the disease and the killing of snails are the best methods for rapid short-term control. The effects of treatment, however, are short-lived when reinfestation is possible. The MOH has changed from planning rapid disease reduction in the population to achieving broader, long-term solutions.

The curative approach is confronted with a lack of trained staff and previous bad experiences with side effects from the drugs. Although too expensive for widespread application, the new drugs are safer and continue to improve. Health education, to be assisted by aid groups, is also planned by the GOS.

KILLING OF SNAILS

The killing of snails with molluscicides has been practiced since 1970 in some areas. Commercial plantations have had some success with such control in canals. The GOS Bilharzia Control Unit, when it was active, virtually eliminated snails from common transmission points in streams after 2 to 3 years of repeated spraying. This GOS program has been reoriented and is considered much less effective at snail control now. The past experience of that program and others has shown molluscicides to have no significant effect in small reservoirs; snail populations showed no appreciable decline after several years of spraying. Large reservoirs would be even more resistant to chemical control. The fencing of reservoirs and timely reservoir drawdown are recommended even if chemical control is used.

Another problem with molluscicides is the need for application every 6 to 7 weeks; this creates a high recurrent expense. Further, at snail-effective concentrations and frequencies, these nonselective molluscicides are quite harmful to fish populations and possibly to a number of other organisms.

Plants toxic to snails, although native to the country, have not yet been shown to be safe for humans and livestock. The use of other animals as predators, antagonists, or competitors, although successful elsewhere, has not been tried in Swaziland. These biological controls probably merit immediate attention and trial implementation. Clearing of aquatic plants is feasible in shallow lake margins and canals and may be within the resources of local residents. Weed clearance has been successful in some parts of Swaziland. Its potential problems include high labor demands and some apparent traditional rules regarding a certain species of plant.

PROGRAMS FOR THE PROVISION OF SAFE WATER

The scheduling of programs for the provision of safe water has been described as reasonable. However, logistical and other problems are potential bottlenecks to real progress and the attainment of these program objectives.

ADEQUATE SANITATION

Adequate sanitation appears to be far in the future, although it is being addressed by the RDA Program and other programs. Extensive placement of latrines promises to be confronted with numerous logistical and organizational problems. This goal, however, should still be actively pursued.

STRUCTURAL DESIGN

Structural design is a control measure given minimal trial so far in the country; however, it is receiving more attention now. A public

Health Engineer was to have arrived in late 1980 to assist in design of GOS rural water systems with disease prevention in mind.

Fencing reservoirs from access by people and cattle is a rather sure method of preventing water contamination. Some fencing is already done by the MOA's Land Use Planning Section for grazing management and fencing should prove to fall within the resources of RDA managers. Obviously, however, plentiful safe water must be provided for people and animals before fencing of reservoirs can be expected to endure. Fences will not last long if they stand between people or livestock and the best available source of water. Further, fences and similar prohibitions do not breed good community relations and are alienating and unpleasant.

Concrete lining, covering, and steep grading of canals may not always be feasible in either small-scale or plantation-scale irrigation. Siphon spillways or other methods for reservoir drawdown may offer promise. Jobin and Jones (1977) considered it fortunate that the snail breeding season coincides almost exactly with the rainy season. Dams would be filling, perhaps to excess, and releases of water could be afforded. A drop in reservoir level of 0.5 meter in 24 hours, followed by gradual (1 week) return, should kill nearly all snail eggs. This covers the entire reservoir and is more effective and less costly than chemicals. Studies may indicate other possible times for effective drawdown. In a series of reservoirs, the lowest dam could effect its drawdown first. This would allow the upstream dam's release to be recaptured in the lower dam, and so on up the series.

The disadvantages of siphon spillways on large reservoirs include the large siphon size required, installation costs, potential loss of needed water, and possible need for repeated drawdowns. Manual control gates may serve as less costly and more efficient level regulators. On small dams, siphon spillways are considered quite feasible and desirable.

In either large or small reservoirs, drawdown may briefly increase the breeding habitat of the Anopheles gambiae mosquito, which is a vector for malaria. Timely refilling of reservoirs after drawdown would minimize this habitat increase.

MALARIA

Historically, malaria has not been considered a primary health problem in Swaziland except at certain locations and times. The disease has been virtually absent in the Highveld region, is considered migrant in the Middleveld region, and has been a significant problem only in the Lowveld region. However, it can be noted that climatic conditions in the Middleveld region are not very different from other African areas which do have a significant prevalence of malaria.

Malaria is caused by a pathogenic organism for which the mosquito Anopheles gambiae is a vector. A mosquito biting an infected person can ingest the pathogen and can later transfer the pathogen to any other person it may bite, thus transmitting the infectious disease among the populace.

Malaria control has usually emphasized control of the vector mosquito rather than the pathogen itself. The control uses one or several of the following techniques:

- chemical spraying of adult mosquitoes in the surroundings;

- chemical spraying of waters which support preadult forms of the insect; or

- eliminating all bodies of standing or slow-moving water which could support the preadult forms.

In Swaziland, chloroquine phosphate prophylactic medicines have also been used as effective suppressants of the pathogens within infected persons.

Treatment and cure of this disease can be done effectively with widely available drugs, and serious damage to the body can be avoided if treatment is sufficiently early. However, treatment is not often sought until late in the disease's attack on the body. Serious fevers; brain damage, especially to infants and children; and death can result from malaria cases untreated or treated too late.

Because the malaria insect vector develops in slow or standing water bodies of even tiny proportions, water development may have significant implications for malaria prevalence. The disease is already considered much more prevalent near large irrigated plantations than elsewhere, due to the reservoirs, canals, and watered fields which can support the insect. It is considered one of the main diseases at the Big Bend clinic, appearing in 8 of 12 exams given in one particular week. Malaria is also reported at the Mhlume clinic.

The increased number of reservoirs and other water bodies resulting from water development may contribute to the prevalence of the disease. On the other hand, it has been proposed that RDA's will facilitate larviciding and spraying of homes because of better access to and proximity of homesteads.

The prevalence of malaria to date has shown an apparent 5- to 8-year cyclical pattern. This pattern is shown in table D-6.

Table D-6
Reported Cases of Malaria

	Year					
	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77
Cases	485 (epidemic)	61	70	169	210	908 (30 deaths)

Source: Jobin and Jones, 1976

Over the past 30 to 40 years, the prevalence of malaria has dropped steeply with control efforts. Still, the 1976-77 figure is higher than any figure since 1948-49. This illustrates the ability of the disease to move rapidly through the population. It also seems to demonstrate the role of control measures. Lapsing of control measures in Mozambique during the independence transition was believed to have been a major contributor to the increase of the disease in that country and in Swaziland. With assistance of the WHO, the Mozambique control program is being rejuvenated. The GOS Bilharzia Control Unit program, based in Manzini, is currently placing emphasis on malaria control and is likely to do so for some time. It is noteworthy that the control program may be unable to conduct effective control over schistosomiasis and malaria simultaneously due to limitations of expertise and resources.

There are reasons to propose that malaria is not a priority health problem in Swaziland. In 1975, while 130,489 attendances were reported for all complaints at government and mission general hospitals, only 210 malaria cases were reported in the country. Even at approximately 900 cases per year, as in 1976-77, malaria would account for less than 1 percent of hospital cases. This does not mean that a much higher prevalence is not possible. Also, there is a tendency not to report the disease due to its rapid onset and impact. Any water development

should be planned with effective malaria control integrated into the scheme.

CONCLUSIONS

"In the long range terms the most beneficial permanent method for bilharzia control is provision of an adequate supply of safe water to households in the endemic zones. Furthermore, this will have a tremendous impact on gastro-intestinal diseases, thus meeting another major health problem." This was the conclusion of the 1976 USAID/WHO report by Jobin and Jones.

The stated goal of GOS is to reduce prevalence of schistosomiasis among school entrants to 5 percent by 1983 and to 1 percent by 1990. This laudible goal stands only a small chance of being achieved under current trends, largely because of reservoir and irrigation developments likely to occur without adequate domestic water supplies. A long-term commitment to the health of the populace is needed.

Efforts of the RDA, RWSB, MOH, and UNEP/WHO/UNICEF programs to bring safe water to the people are likely to make significant contributions. These programs and others will need substantial consistent support in order to keep pace with population growth and to avoid disillusionment in the populace.

Irrigation developments of any kind will probably increase the availability of water to rural residents and will certainly have the potential, therefore, to make significant improvements in health conditions. However, that water may very well be infested by pathogens and

parasites. The populace will view the ready supply of water in canals and reservoirs as a boon. They will not realize, however, the de facto negative health impacts likely to result from their use of the water. Therefore, irrigation water supply should not be used to justify delays in providing truly potable water to the populace and in adapting structural design and other controls to minimize chances of infection.

Existing irrigation schemes should provide safe water to their employees and area residents. Future schemes should include such provision in the planning stages. It cannot be assumed that any irrigation scheme will inevitably provide domestic water supply after the irrigation network is in operation. This is illustrated by a large existing scheme that has not made such domestic supply provisions after 30 years of operation.

The tremendous potential of irrigation schemes in benefiting local health conditions is indicated by the relatively small domestic water volume required, compared to the irrigation water volume. Integration of domestic water planning in irrigation scheme planning would facilitate a comprehensive water supply with both economic and social benefits. Irrigation planning without domestic water planning would aggravate an already significant national health problem.

The importance of cooperation between government and any commercial scheme is indicated by the fact that one-fourth to one-half of Swaziland's urban population is in company towns. These people also need safe water and sanitation, for which the government is not directly responsible in such communities. A related role of such schemes is the clinic facilities they normally provide. These clinics are typically well staffed and well equipped and are able to facilitate the government's objectives in rural areas.

Experiences in Puerto Rico, Japan, and Venezuela have indicated that a 1-percent schistosomiasis rate in school entrants is possible even without chemotherapy. What is required is a national effort, well advised and supported, which will allow for safe domestic supplies in all water resources development plans.

The references used in this section are 16, 17, 19, 24, 25, 26, 31, 34, 45, 51, 52, 53, 72, 75, 77, 80, 81, and 82, as listed in Section T.

SECTION E

PHYSICAL WATER QUALITY

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SECTION E
PHYSICAL WATER QUALITY

For the last few years the Swazi government has had a monthly program of stream sampling and water quality testing on the major streams and some of their tributaries. Thirty-seven sites are sampled each month. The tests run on these samples include pH, turbidity, alkalinity, hardness, and chemical oxygen demand.

The government has also set up a sampling and testing program of the domestic water supplies. These tests include pH, turbidity, alkalinity, hardness, and certain media tests for bacteria. Treated sewage is also sampled. Biological oxygen demand (BOD) is the primary test used to determine the effectiveness of sewage treatment.

Throughout the country, the water quality is generally good. The pH of streams and ground water averages about 7.2 and ranges from 6.1 to 8.9. Turbidity averages about 16 Formazine Turbidity Units (FTU's) and ranges from zero to 300 FTU's. Alkalinity averages about 30 parts per million (ppm) and ranges from 2 ppm to 172 ppm. Hardness averages about 40 ppm and ranges from 8 ppm to 200 ppm. One station (a pumphouse at Lubuli) had samples which were extremely high in total dissolved solids, hardness, and alkalinity. Hardness and alkalinity ranged as high as 1,020 ppm and 1,300 ppm, respectively. Lubuli is in the eastern Lowveld region; the soil in this area is derived from basalt and would normally have some higher concentrations than stations in other areas. These values, however, appear to be extraordinarily high and need to be investigated further.

The sewage treatment testing, which is done for treatment plants at Mbabane, Manzini, Matsapha, and Hlatikulu, shows that the systems are normally effective in reducing the 5-day BOD by 95 percent. In one instance at Hlatikulu, the 5-day BOD was reduced by only 78 percent. The reasons for this exception could include temporary overloading, either organic or hydraulic; introduction of a toxic element; or some system failure. In any event, the incident appears to be an isolated case and the overall operation of the treatment facilities is fairly effective except during dry periods when oxidation ponds become overloaded causing them to become septic.

WASTEWATER SOURCES

URBAN RUNOFF

With the exception of turbidity, there are probably few water quality problems emanating from the urban areas. As stated previously, the operational sewage treatment facilities are adequately reducing the organic waste load to the rivers except during dry periods. There is little opportunity for other pollutants to enter urban runoff because Swazis do not practice intensive landscaping as do western cultures. Also, they do not have a climate that requires special seasonal maintenance such as road salting for winter snow and ice.

Although water quality problems within the urban area are minor now, care must be taken to ensure that problems do not develop. The likelihood of such problems developing is increasing as more of the rural population migrate to the urban areas and establish residence in

homes without sanitary facilities. Because the population was so predominantly rural in the past, there was not a sufficient population concentration to cause water quality problems to develop. As the concentration of persons in the Mbabane-Manzini and Matsapha areas increases, such problems can be expected to develop if preventive measures are not taken.

INDUSTRIAL RUNOFF

Runoff from industrial areas could be causing some undetected water quality problems. Although some treatment exists, the degree and the quality of this treatment are now known. Furthermore, past breakdowns in the wastewater treatment systems have resulted in severe water quality degradation and environmental damage. A more comprehensive water quality monitoring and testing program, particularly downstream from the industrial areas, would help to protect against pollution from these sources.

RURAL RUNOFF

Rural runoff in Swaziland, as in the rest of the world, has the potential to create water quality problems. This is especially true for the intensively irrigated areas where overirrigation is intentionally practiced in order to prevent salt buildup in the soil. The dissolved solids concentrations in the rivers are low and it is unlikely that an increase in concentrations from irrigation return flows would have any adverse effect on water quality. In fact, it could benefit the rivers by increasing their aquatic productivity.

The potential water quality problem, therefore, is not with dissolved solids; it is with chemicals such as pesticides and herbicides which could find their way into streams via return flows or precipitation runoff. As with industrial runoff, a more comprehensive stream

monitoring and testing program could help to protect against this problem. If a problem does exist or does develop in the large irrigation projects, the controlled return flow system of such projects enhances the opportunity for treatment.

Other nonpoint agricultural runoff from cultivated fields and high livestock concentration areas is a source of water quality degradation, especially during the early part of the rainy season when the land is initially washed by rains. Little can be done to treat this problem. The Swazi practice of keeping their livestock with them, and thereby dispersed, is probably the most effective way of preventing serious water quality problems from developing in any given stream.

By far the worst water quality problem is the turbidity generated during periods of high flow. Vegetation burning and overgrazing occur in some areas and leave large expanses of soil unprotected when the first rains come each season. Erosion and the resultant sediment in waters can cause considerable damage to aquatic resources and main stem water storage facilities. In order to prevent this, more effective land conservation measures will have to be implemented and more emphasis will have to be given to this problem by the government.

USE CONSTRAINTS BASED ON WATER QUALITY

FISH AND WILDLIFE USE CONSTRAINTS

Measured water quality in Swaziland appears to present a few serious constraints to fish and wildlife uses. The pH is occasionally low and could hinder fisheries development in some cases. Seasonal

turbidity could pose a problem to riverine fisheries, and this could increase with development. The tolerances of Swaziland species to various parameters should be determined, at least by literature search, to confirm this report's conclusion.

pH

The natural pH of 6.1 to 8.9 in Swaziland corresponds closely to the 6.5 to 9.0 range recommended by the U.S. Environmental Protection Agency (EPA) for freshwater aquatic organisms. When pH values range between 5 and 9, they are not directly lethal to fish. The likelihood of biological problems increases with the speed and degree of deviation from that recommended range or from the normal seasonal range. Biological effects of low pH could be more significant in warm-water than in cold-water fisheries. Bass, for example, would have more problems with low pH than trout. Further information is contained in the Fisheries Section.

The toxicities of carbon dioxide and of pollutants are considerably enhanced by the lowering of pH values. On the other hand, rapid increases in pH can increase ammonia to toxic levels; ammonia is 10 times as toxic at pH 8 as at pH 7. These toxic reactions due to pH change are possible in Swaziland and should be studied. The possible limit imposed on bass success by low pH should also be investigated. Other than these exceptions, however, the entire range of pH 6 to pH 9 is considered highly protective of most freshwater aquatic organisms, and Swaziland's waters should generally pose no problems with pH.

TURBIDITY

An increase in solids carried by water has a number of potential detrimental effects. The increase may reduce light penetration, and thus photosynthesis and food supply; increase heat absorption and stratification; smother benthic organisms; block spawning beds; hinder egg development; hinder fish movement and migration; absorb oxygen; or directly injure or kill fish.

Present turbidity levels in Swaziland are quite low during most seasons and should present no perennial constraints to fish and wildlife uses. Organisms in water bodies with low turbidity, however, are most sensitive and susceptible to increases in turbidity. Swaziland's rivers and reservoirs would, therefore, need close protection to ensure their biological integrity.

In areas with low turbidity in the United States, rather strict protection is ensured by setting turbidity increase limits. Where background turbidity levels are low (e.g., below 50 FTU's), the limits allow nil or only very minor increases. Where turbidity is already at medium levels (50 to 250 FTU's), the limits allow a 10-percent maximum increase. Where background turbidity is higher, absolute maximum limits are set (e.g., 20 to 30 FTU's over background). Such standards might be advisable for Swaziland.

Seasonal rains apparently cause considerable turbidity in rivers, as indicated by sediment deposits on river bottoms. This could pose a seasonal constraint to riverine fishery development, especially if the rains coincide with the spawning season. Related to this is the possibility that river bottoms are unsuitable for spawning by trout. Trout need gravel in which to deposit their eggs. The sandy sediments common to Swaziland's rivers may preclude widespread success by at least that species.

ALKALINITY

Alkalinity is a measure of water's buffering capacity, which is its ability to neutralize acidic or caustic inputs while maintaining a pH suitable for the activity of its existing biological community. Alkalinity in nature occurs over a very broad range (from 10^{-2} to 10^{-5} equivalents/liter), which is tolerated by organisms. Most waters have an alkalinity of at least 20 ppm and a level of 400 ppm is not considered undesirable. The measured values of 2 to 172 ppm in Swaziland,

with an average 30 ppm, will probably fall well within tolerable limits of fish and other wildlife.

HARDNESS

Hardness includes both alkalinity (the carbonate component) and a noncarbonate component to determine metallic ion contents of a water sample. It can, therefore, exceed alkalinity.

Increased hardness can reduce the toxicity of some substances to aquatic organisms. The mortality rate for rainbow trout due to copper and zinc, at hardness of 100 ppm, was reduced four times from the mortality at hardness of 10 ppm. Swaziland's hardness value of from 8 to 200 ppm, with an average 40 ppm, and associated alkalinity value appear high enough to preclude serious constraints to fish and wildlife use.

DOMESTIC USE CONSTRAINTS

As revealed by the previous general water quality discussion, the water quality for domestic use is quite good. With the possible exception of some areas in the eastern Lowveld region, the current inorganic chemical samples indicate that no treatment requirements are necessary because concentrations are well within acceptable limits.

There is, however, one known water quality problem and others may exist. Corrosion is a problem known to exist to some extent in all of Swaziland's natural waters because of the common occurrence of pH below 7.0. Water with a pH less than 7.0 will attack corrosive metals and will, in time, destroy them. The solution to this problem is the use of noncorrosive metals or treatment of the water to raise its pH above 7.0. Corrosion could, therefore, require an added cost and/or some intensive treatment; it does not, however, represent a serious health problem.

Another potential problem could have some associated health effects. This problem is the possible contamination of water by industrial discharge and agricultural runoff from within Swaziland's borders or from without. Discharges from the wood processing industry, from upstream neighbors, and, to a lesser extent, from the Matsapha complex represent a health hazard to Swazis located downstream from these sources. Water quality information on these upstream discharges appears to be essentially nonexistent and should be investigated further.

Water quality contamination from agricultural runoff probably poses less of a threat to domestic use than industrial discharge because most of the large, intensively cultivated areas are downstream from the major population areas in the Lowveld region. The exceptions to this are the Malkerns area and possibly the Highveld forestry areas which could be sources of pollution depending on their management practices. Although not a potential threat to Swazis, agricultural runoff could pose a hazard to downstream domestic users in other countries. This is particularly true of those users that are downstream from the large irrigation schemes that overirrigate in order to leach salts from the soil. The salts themselves should pose no domestic use problems, but other chemicals such as pesticides and herbicides that are leached out of the irrigated soils could cause problems.

Although agricultural runoff problems appear to be minor now, problems could result if large-scale irrigation schemes are developed in the future, particularly in the Highveld or Middleveld regions. The degree to which these problems develop will depend on how they are addressed during advanced planning and project implementation.

AGRICULTURAL USE CONSTRAINTS

Any water quality constraints to agriculture would generally be due to the same factors which constrain domestic use. The pH value,

for instance, while not being low enough to have any apparent effect on crops, could cause problems with any corrosive metals used in irrigation transmission and distribution systems.

As with domestic use, irrigation use of water could be jeopardized by water contaminated by upstream users located either within Swaziland or outside the country. This would be more likely to occur in the major basins like the Lomati, Komati, and Usutu, where a considerable area is drained upstream from the country's borders. Unlike domestic water, which could be treated if found to be contaminated by upstream discharges, irrigation water could be treated only at great cost because of the large volume involved. This possible constraint will have to be considered during the advanced planning of any future irrigation schemes.

The potential for downstream agricultural reuse of water should be impaired only slightly, if at all, by its previous use upstream. In some instances, agricultural use upstream could even enhance downstream agricultural use. Although surface runoff and leaching of pesticides, herbicides, and fertilizers from fields would cause some concern among downstream domestic users, they could be considered as enrichment to the nutrient-poor receiving streams for agricultural users. Whether this runoff would be beneficial or not would depend on the particular chemicals. Information currently available on chemicals in use, and on their adverse effect on nontarget crops and on future cropping patterns, is insufficient to make a specific judgment on this effect. As with the other uncertainties discussed above, this potential problem must be considered during any advanced detailed planning of irrigation schemes.

Although turbidity or large sediment volumes would have little direct effect on agriculture, they could have an indirect adverse effect due to accelerated sedimentation of instream irrigation storage reservoirs. As mentioned earlier, better land conservation practices would help avoid this problem.

CONCLUSION

In general, the water quality of Swaziland is believed to be good with few limitations to its use. A low pH problem could have an adverse effect on corrosive metals; this would require either water treatment or the use of noncorrosive metals and could also be a partial constraint to fishery development in some instances. A more comprehensive water monitoring and testing program, particularly downstream from known industrial and major agricultural areas, would better enable the government to protect the quality of its very important water resources. Better soil conservation would reduce turbidity and sedimentation problems, thereby protecting aquatic resources and instream water storage projects.

The references used in this section are 15, 47, 50, 73, 77, 82, and stream sampling records of the Water and Sewerage Board, as listed in Section T.

SECTION F

FISHERIES

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FISHERIES

Swaziland contains a variety of water bodies and, therefore, a variety of fish habitats. The status of fisheries in Swaziland is yet undetermined, but the potential appears large. Although exploitation of fisheries has not played a major role in the history of the Swazi people, fisheries are receiving increasing attention and may make significant future contributions to the country's food stock and economy. The Ministry of Agriculture and Cooperatives (MOAC) has established objectives for exploring the country's fishery potential, for promoting fish ponds, and for promoting fishing in the dams and rivers. Development of fisheries is partly tied to development of water resources.

The main developments available to the country include hatcheries, fish ponds, fish farms, commercial and private lake fisheries, and river and stream fisheries. These developments can be used for commercial food fisheries, subsistence food fisheries, or recreational fisheries. The food and the recreational potentials will be considered here, with emphasis on food fisheries. Recreational fisheries will be treated further in the Recreation and Tourism Section. Swaziland's main fish species are listed in table F-1.

LAKE FISHERIES

Of all possible fishery developments, it appears that lake fisheries stand to gain the most from water resource developments because of the role of reservoirs. Although there are currently very few lakes

Table F-1
Important Fish Species in Swaziland

Scientific Name	Common Name
Indigenous Fish	
Clarias gariepinus	Catfish, barbel
Eutropius depressirostris	Silver barbel, squeaker, butter barbel
Labeo cylindricus	Cylindrical mudsucker
Barbus marequensis	Large-scaled yellowfish
Tilapia rendalli	Red-chested tilapia (formerly Melanopleura)
Gnathonemus macrolepidotus	Bottle-nose
Sarotherodon mossambicus	Red-fin tilapia (formerly Tilapia)
Hydrocynus vittatus	Tiger fish
Barbus polylepis	Small-scaled yellowfish
Exotic Fish	
Micropterus salmoides	Largemouth bass
Salmo gairdneri	Rainbow trout

in the country, a number of fish species in Swaziland can do well in lakes. These species, several of which are palatable and desirable food fish, could increase significantly with an increase in available habitat caused by impoundments for storage reservoirs. The indigenous Tilapia and yellowfish should thrive in reservoirs, particularly medium-to-warm temperature waters, along with catfish, barbels, and perhaps some others. The exotic largemouth bass and rainbow trout could also do well in reservoirs.

Tilapia is a popular African food fish of medium size; it is considered excellent eating and has some added value as a sport fish. It can breed every 3 to 6 weeks and thrives best in warm waters. The Tilapia survives marginally at water temperatures of 13° C, grows nominally at 16° to 18° C, and flourishes at 20° to 22° C. Thus, its benefits would be marginal from dams in the Highveld region. It could do well, however, in the Middleveld region and might prosper in the Lowveld region and has also proven successful in sewage ponds.

Yellowfish is a less attractive although larger and more widespread food fish in Swaziland and has considerable value as a sport fish. It is considered a tasty though somewhat boney fish. Yellowfish is the most widespread fish in the Natal Province of the Republic of South Africa (RSA); it occurs in all rivers and tributaries up to and beyond 1500 meters above mean sea level (m.s.l.). This indicates its ability to survive in cool waters. Its presence as the most frequent catch after Tilapia in the 1972 Sand River Lake Survey also indicates its ability to do well in reservoirs below 500 meters m.s.l.

The catfish is a large fish of excellent palatability and is a scavenger that does well in reservoirs, especially in medium-to-warm waters. As opposed to the gill net method which is best suited for most other species, a long line is the best fishing method for catfish.

Barbels are known to do well in lakes such as Lake Kariba in Zambia, Lake Victoria in Kenya, and Sand River Lake in Swaziland. This fish is somewhat less prolific than the others, but it reaches quite a large size and is considered good eating.

Largemouth bass have not yet developed conclusively as a viable productive species in Swaziland. This species is desirable for food and especially for sport and could, in time, prove to be a valuable component of the nation's lake fisheries. Largemouth bass fare best in warm waters, surviving temperatures below 10° C but preferring and thriving in temperatures up to 35° C. Thus, they offer most potential in the Lowveld region, although they have also been used at elevations up to 1500 meters m.s.l. in the Natal Province. It is considered exceptional, however, for any Natal Province region lake to maintain good bass populations without close management, due to the eventual losses of lake productivity and natural upsets of bass populations. This may prove to be the case in Swaziland; the low mineral content waters of moderate acidity may not allow the productivity best for bass success.

Bass are also valuable as a predatory control on populations of species such as Tilapia, which they eat with size selectivity. Tiger fish are unlikely to breed in lakes, and so the predatory selection role might be accomplished by bass.

Tiger fish are an indigenous species which are valuable as selective predators on other species. Although they may not breed in lakes, they could be periodically stocked. Tiger fish are not a palatable food fish.

The Tilapia and catfish are the main fish marketed in smaller local markets in Swaziland. Carp, which are commonly stocked in fish ponds with Tilapia, are more often marketed through city stores.

All the species described above, except for tiger fish, offer potential for good food fisheries in any warm-water reservoirs that may be developed, if some management is provided. Management would include introduction of predatory fish and harvesting, in order to keep populations thinned and individuals larger, and restocking when necessary. Such management would probably not be a responsibility of the MOAC Fisheries Section. This agency's expressed priority lies in fish ponds, extension advice, and similar rural developments. While the MOAC could do surveys and stocking of developing fisheries and could help manage treatment lagoons or medium-sized reservoirs, it may not be able to meet the management needs of recreational or large commercial fisheries.

Cool- or cold-water reservoirs would be more suitable for species other than those mentioned above, except for the cool-water tolerance indicated for yellowfish and perhaps for bass. Rainbow trout are being developed primarily as a stream fish for sport. However, they are also known to prosper in cold or cool lakes. Suitable lakes would need temperatures below 21° C, preferably around 13° C, with a tolerable maximum of about 27° C. The cool temperatures are desirable to keep oxygen

above the critical level of 3.5 parts per million (ppm), preferably between 5 ppm and 10 ppm (or saturation). Springfed lakes, deep lakes, or those at high elevations would more easily maintain the low temperatures, and lakes that would become persistently stratified would not be suitable. The lake should also have gravel beds for spawning, unless continuous restocking is feasible. As with bass, trout have not been shown to be a viable self-supporting species in Swaziland and could require intensive management. Experiments with stocking are still in the early stages. Rainbow trout would not be expected to become a major part of reservoir fisheries, but given suitable conditions, they might be able to maintain a harvestable population.

One qualifying factor in the potential of reservoirs is the seasonal water level fluctuation as storage accumulates and is depleted annually. These water level changes would cause stress to fish populations because of the resulting low stage warming of water temperatures, the decline in oxygen levels, and the exploitive overfishing.

RIVER AND STREAM FISHERIES

To date, river and stream fisheries remain undeveloped, and their status and potential are unknown. No descriptions of species are, therefore, included herein. This complicates any projections regarding impacts on these fisheries and points out a need for studies on any proposed project. The potential of any water development to benefit rivers and stream fisheries appears limited, while a number of potential detriments to these fisheries can be suggested.

One possible benefit to stream communities from water developments could be the guaranteed minimum flows which might be available from reservoirs, canals, or wells. Most major rivers have year-round flow. Smaller rivers or streams, however, may often run very low or dry. Managed reservoir releases would facilitate fisheries management as long as water was available from the reservoir. Large wells or canals could also serve as instruments of guaranteed flow to streams they might be able to feed. Two other possible benefits--fertilization of streams by agricultural chemicals and provision of migration staging areas by reservoirs--will be mentioned within the following discussions of potential detriments.

The major probable impact of water development on streams and rivers would be their impoundment. The probable results are unknown as long as the fishery remains unstudied, but possible results are described below.

Inundation of rivers could ruin the habitat of riverine fishes. An example is the tiger fish, an indigenous riverine species which is an important predatory control fish and a sport fish. It can survive in lakes, as shown by its presence in Van Eck reservoir near Big Bend. However, it is considered a migrant or accidental visitor there and has not yet been found in the Mnjoli reservoir. Tiger fish are projected not to breed in reservoirs because they need oxygenated, fast-moving warm water to survive as a species. Trout also require oxygenated water and so prefer fast cold-water rivers or streams. The Komati and Lusushwana (Little Usutu) rivers, for example, may have the potential to become valuable trout streams. Their impoundment could somewhat reduce the nation's prospects for an active trout fishery.

Another potential detriment could result from the blocking of fish migration routes by dams. Species such as Labeo victorianus in Kenya are known to show a "positive response to the influx (into the lake) of

flood water, which leads mature individuals to sites (up tributaries) where spawning activities can be successfully carried out" (Bowmaker in Ackermann, et al.). Tiger fish, catfish, and cylindrical mudsuckers (Labeo cylindricus) and other Labeo species have also been shown to migrate upstream for breeding purposes. Tilapia have been shown to migrate upstream for feeding and possibly for breeding. Successful migration in certain reaches could be prevented by dams. Depending upon the distances usually traveled by migratory species affected, considerable lengths of rivers could be depopulated of these species, and food chains could be upset.

Moderating considerations here are that these migrations may not be widely prevalent or necessary in Swaziland. The migrations cited above used lakes as staging areas for entrance into the tributaries. Therefore, new impoundments could conceivably serve as new staging areas from where fish could initiate migration routes previously unavailable. This could be a benefit to those species. Further, some migrating species spawn along the migration route, although more randomly and less effectively than at their spawning grounds. These species could, thus, have some small spawning success despite being unable to pass upstream to their preferred spawning area.

When considering both lake fisheries and riverine fisheries, as well as possibly other fishery areas, the following possible impacts of water development can also be suggested.

A potential detriment to fisheries would result from drawdown of water bodies by irrigation or other heavy uses. In reservoirs, rivers, or fish farms, reduced water levels can seriously damage fisheries by reducing the oxygen available, raising temperatures, or interfering with migration, breeding, or food organisms. These drawdowns might be seasonal in reservoirs or perennial in the rivers located downstream from heavy uses. Minimum flow stipulations could be considered in water developments.

Another detriment could be the effects of return flows or effluents from irrigation, industry, or cities. Fertilizers, herbicides, insecticides, chemical and biological wastes, heat, and oxygen deprivation could all reduce water quality below fishery support levels. Past unintentional spills of industrial byproducts have shown the devastating effects of such pollution, as well as the difficulty in exercising authority over such pollution sources.

One moderating factor here is the current low level of use of agricultural chemicals. While this may be true in most areas at this time, the increasing commercial operations will be applying increased amounts of chemicals in efforts to maximize returns. Another possible moderating factor is that the typically soft, low-mineral waters of Swaziland's rivers could benefit from inputs of fertilizer. The added nutrients could facilitate algal growth; it would allow higher populations of invertebrates and of fishes and would boost productivity generally. Such benefits would, however, accrue only within a certain range of fertilizer input concentrations and such inputs might coincide with damaging pesticide inputs. Once again, studies of waters to be affected and of the prospective return flow or effluent qualities are advisable.

FISH PONDS

One of the main programs of the MOAC Fisheries Section is the promotion and establishment of fish ponds, primarily on Rural Development Areas (RDA's) but also wherever the populace is eager for a pond. The program began in 1975, and, by 1977, there were about 200 fish ponds on RDA's. As of July 1980, there were about 266 ponds recorded on the RDA's, although the exact location of all ponds recorded in the past is

not certain today. According to the Library of Congress, Swaziland has "excellent potential for fish pond development." The efforts of the MOAC include extension advice, stocking of fish, and some harvesting. The local people, particularly the women, provide the labor needed to excavate, to manage, and to harvest the pond. Fish ponds will probably be the predominant effort of the MOAC Fisheries Section for a number of years.

These ponds can provide both subsistence and commercial fish harvests. They are recommended to be about 200 square meters in size. Tilapia and mirror carp are the main species stocked. Theoretical projections for mirror carp stocked at a rate of one per square meter give a weight attainment of 800 to 900 grams (gm) after 9 months. Experience shows actual attainment of 700 gm after 12 months, with some supplemental feeding and fertilization.

Fish ponds can benefit from dependable inflows and, so, could benefit from water developments which would make water available. Reservoirs and canals could serve that purpose, as could tapping of springs, streams, or wells. Due to the scattered location of fish ponds, they would benefit more from scattered water sources, such as springs, streams, and canals, and less from large reservoirs. However, fish ponds do not actually require such flow inputs and are not, in fact, designed along such criteria. Water developments, therefore, would probably have limited impact on the fish pond program, unless the program was incorporated into water development projects with fish ponds located on project lands and along canal routes.

FISH FARMS

Fish farms are largely undeveloped in the country. A private party at Motjane has a few ponds. A government farm is experimenting with trout, and another farm is believed to be under development by the Swaziland National Trust Commission.

These closely managed types of facilities produce fish which are harvested at specific sizes after their peak growth period. Trout are well suited to farming operations where water is sufficiently oxygenated, cold, and dependable. Fish farms require large raceways, monitored waterflows and water qualities, and supplemental feedings. Because of these requirements, fish farms can best be developed near major springs, rivers or wells, or near reservoirs, where guaranteed or regulated flow may be available. Because they would be less numerous and less scattered than fish ponds, fish farms could benefit more from storage reservoir development.

FISH HATCHERIES

Water development has a relatively minor potential to benefit the government's fish hatchery program. Fish hatcheries can benefit from guaranteed or controlled flows and, in fact, must have regulated, clean input flows for success. They could, therefore, benefit from development of major springs, streams, wells, canals, or reservoirs.

There is currently an MOAC Fisheries Section hatchery at Mbabane and another at Nyetane dam; these are used primarily to supply the fish pond program but also to supply lake fisheries and future trout fisheries. The MOAC anticipates little need for new hatchery development other than a possible facility at Manzini. Therefore, water resources development promises to have little impact on the fish hatchery programs. Still, individual water developments would do well to coordinate with MOAC in this regard.

There is also a possibility that certain water developments could adversely affect fish farming or hatcheries. Reservoir development could inundate natural drainageways suitable or in use for fish farming or hatcheries. Industrial and agricultural return flows could deteriorate water quality below useful levels. Drawdown of rivers for irrigation or other uses could diminish the flow below critical levels. To date, none of these adverse effects appears imminent. The potential benefits and damages to fish farm and hatchery development should be considered in individual water developments.

EFFECTS OF pH

As mentioned in the Physical Water Quality Section, low pH values in Swaziland have been considered a possible constraint to fisheries development. Recorded Swaziland pH ranges from 6.1 to 8.9. The European Inland Fisheries Advisory Commission has determined that there is no definite pH range which is harmless to fish, or beyond which damage to fish is certain. The Commission's findings regarding pH in the range of 5 to 9 are summarized in table F-2.

Table F-2
Effects of pH on Fish

pH Range	Effect on Fish
5.0 to 6.0	Not harmful unless free carbon dioxide (CO_2) exceeds 20 ppm or iron salts are present which form ferric hydroxide.
6.0 to 6.5	Not harmful unless free CO_2 exceeds 100 ppm.
6.5 to 9.0	Harmless, although this range may affect the toxicity of other poisons.

Biological effects of low pH could be more significant in warm-water fisheries than in cold-water fisheries, as indicated by table F-3 which summarizes world literature on pH. The pH tolerances of some United States fishes are discussed in the following paragraphs, beginning with warm-water species.

The fathead minnow is a warm-water fish well adapted for high pH. Its pH tolerances are indicated in table F-4.

The largemouth bass is a species which does better in warm water than in cold. Lower limit pH values were not secured. Test reports indicate, however, that pH above 9.4 is lethal to at least part of a population, and 10.9 could be considered generally lethal. Low pH has been considered a possible limiting factor to bass success in Swaziland.

The white sucker is a fish of cool streams. Its prolarval forms develop normally at pH above 5.41 but become deformed at pH 4.97.

Brook trout eggs in one test survived to hatching at success rates that roughly increased with pH, as shown below.

pH	4.65	4.97	5.64	8.07
Success (percent)	76.4	84.2	82.8	90.3

Table F-3
The Biological Structure in Fresh Water at Various pH Values

Range	Warm-Water Species	Cold-Water Species	Benthos	Microorganisms	Algae	Plants
6.5–7.0	Full fish production	Full fish production	Relatively normal, molluscs occur commonly	Small numbers of fungi; various bacterial species occur; microflora quite normal	Essentially normal	Normal flora
6.0–6.5	Maintenance and growth	Full fish production	Same as above	Same as above	Same as above	Same as above
5.5–6.0	Maintenance but no carryover	Maintenance and growth	Diverse fauna or benthic organisms; number of different species. Blackflies, mayflies, and stoneflies are present in moderate numbers	Yeasts and *Thiobacillus-Ferrobacillus* bacterial group are important; bacterial species diversity decreases	Diatoms, Flagellates, and green algae are common; *Oscillatoria* may be found; only blue-green algae commonly occurring at pH lower than 7.0	Most aquatic plants will grow at this range if substrate, water velocity, and fluctuations are satisfactory
5.0–5.5	No viable fishery	Maintenance but no carryover	Same as above	Same as above	Same as above	Same as above

Source: Katz, M., 1969, in American Fisheries Society, 1979

Table F-4
Fathead Minnow pH Tolerances

pH	Effects
4.5 to 5.2	Abnormal behavior and deformed fish
Less than 5.9	Reduced egg production and hatchability
6.6	Marginal for vital life functions
7.0 to 8.5	Apparent optimal range
Up to 10.0	Survival up to 6 months

Brook trout have a lower lethal limit of pH 3.2 to 3.6. They avoid pH of 4 to 4.5 and select water at pH 6.7 to 8.0. The upper lethal limit for these fish is about pH 9.8.

The references used in this section are 14, 15, 24, 26, 31, 41, 50, 51, 73, and 76, as listed in Section T.

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RECREATION AND TOURISM

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RECREATION AND TOURISM

TOURISM

Tourism in Swaziland is comprised mainly of weekend visits by residents of the Republic of South Africa (RSA). These visitors come to take advantage of Swaziland's casinos, resort hotels with recreational facilities and spas, and scenery. Recreational fishing, boating, and game viewing have not been significant attractions.

Swaziland has approximately 2,200 hotel beds in 27 hotels, which accommodate 90 to 95 percent of all visitors. These hotels are heavily concentrated in the Mbabane-Ezulwini area; the main casino and other facilities are in the area. This tourism contributes to the predominant urbanization of the Mbabane-Manzini corridor. There are also two caravan parks, a year-round rest camp, and a few seasonal rest camps. Other facilities serving the visitors include restaurants, conference rooms, and cinemas. Statistics concerning hotel capacities and visitation rates are shown in table G-1.

The table shows that arrivals decreased and the average stay length remained steady from 1975 to 1977. A current objective of the government is to increase the average stay by 1 day. This would greatly increase economic turnover but would require an industry which was diversified to alter the current preeminence of the casino-resort attractions. The table shows stay length and economic turnover have recently paralleled each other. If these were assumed to be directly related, an additional day of visitation could be said to offer an increase in economic turnover of 40 percent, to E11.6 million.

Table G-1
Tourism and Hotel Statistics

Year	Arrivals	Annual Increase (percent)	Average Stay Length (days)	Hotel Beds	Annual Increase (percent)	Occupancy (percent)	Economic Turnover (E million)
1973	89,153	--	2.8	1,543	--	50.6	5.8
1974	96,123	+ 7.8	3.1	1,730	+12.1	50.1	7.4
1975	132,305	+37.6	2.5	1,802	+ 4.2	50.7	8.8
1976	115,352	-12.8	2.5	1,831	+ 1.6	43.7	8.2
1977	109,688	- 4.9	2.5	1,976	+ 7.9	38.5	8.3

In 1977, the tourism industry employed about 1,600 people, which was about 62 percent of the employment target of 2,600 jobs set in the Second National Development Plan. The Third National Development Plan has established the following objectives for tourism development:

- decentralize the industry from the Mbabane-Ezulwini area to take advantage of widespread scenic, historic, and recreational attractions and to distribute the benefits;

- develop facilities ranging from luxurious to moderate, so that Swazis can participate in tourism;

- extend marketing of Swaziland's attractions to a variety of potential tourists;

- encourage participation of Swazi nationals; and

- effect controls to avoid sociocultural problems that could derive from rapid development.

Because the government's objective is to decentralize tourism, new attractions in the southern and northern portions of the country have been pursued. These could supplement the new casinos in those areas. Water developments such as reservoirs could be especially useful in these less developed parts of Swaziland.

RECREATION

PROTECTED AREAS

The government is pursuing the development of new recreational attractions, especially protected natural areas and fisheries, as well as more casinos. Thirty-one protection-worthy areas have been identified by the Swaziland National Trust Commission and are proposed for protection; these include or would alter the five existing protected areas. The areas would be designated as national parks, nature reserves, national landscapes, and national wetlands (the last two types would be administered as nature reserves).

The natural wetlands and drainages of Swaziland have been destroyed by drainage and cultivation or are disturbed by man's activities, livestock, and pets. Artificial water bodies are the focus of the proposed national wetlands; these range up to 4,280 hectares (ha) in size.

Waterfowl and wading birds are potentially abundant and would be attracted to new reservoirs; the birds attracted would depend on the type of reservoir. These areas would be very attractive to tourists. Planning for development of wildlife areas and tourism on an artificial water body is currently underway for the new Mnjoli reservoir. Various proposed use zones would accommodate day-visitor use, Swaziland National Trust Commission development, and nature reserve conservation next to a bird and fish sanctuary.

Swaziland's terrestrial wildlife has also been reduced dramatically. Considerable restocking might be necessary before the protected areas could be attractive for game viewing or for hunting. Swaziland's potential is great, however, and outstanding game attractions may develop in

time. The famous Kruger Park, which is located in the RSA, is not far away.

The lack of water has been credited with saving large unprotected areas of Swaziland and other African countries from serious damage by man's agricultural industry and settlements. The provision of water in these areas is seen as a precursor to the loss of their scenic and natural values. In proclaimed protected areas, however, water development could facilitate development of the needed management and tourism infrastructure.

FISHERIES

Besides creating wetlands and facilitating protected area infrastructure, water development could significantly affect Swaziland's fishery potential. Both foreign and resident non-Swazis apparently enjoy sport fishing and would take advantage of increased sport fisheries. As mentioned in the Fisheries Section, water development would offer primarily positive impacts on lake fisheries and predominantly negative impacts on river fisheries because of impoundments.

Sport fish which could flourish in reservoirs include Tilapia, yellowfish, and largemouth bass; these are listed in decreasing order of abundance and in increasing order of sport value. Rainbow trout are not yet well established in the country but could do well in the cooler lakes, if a gravel bottom were available for spawning. All these fish are desirable for eating, although yellowfish are a bit boney.

There are several fishing clubs in Swaziland that are made up primarily of non-Swazis at settlements such as Piggs Peak, Usutu, and Manzini. The club members fish actively in many areas and also stock dams. These clubs would take advantage of any new fisheries that might be developed.

South Africans are considered outdoor-minded and fish actively in the Natal Province of the RSA. The Natal Province has excellent fishing and offers habitat at least as good as Swaziland's for all Swaziland's main species. An exception could prove to be an unusual trout potential in some parts of Swaziland's Highveld region streams. South Africans may not selectively prefer Swaziland's fisheries over Natal Province fisheries. However, Lesotho's restocking program has succeeded in drawing South Africans to fish for record trout. South Africans may well appreciate Swaziland's fisheries enough to visit the country more often and for longer periods. Fisheries in Swaziland would offer new variety, pleasant sceneries, and a relaxing atmosphere, in addition to the availability of casinos and other established attractions.

The perspective visitors would require roads for easy access, some small boat access, and picnic areas. Weekenders would require convenient access to hotels, other facilities, and, perhaps, towns. These things are especially necessary if the visit is to be extended beyond the current average stay. Good access may be of less importance to trout fishermen.

Swazis generally are not considered sport fishermen. The Swazi urban middle class has only a low potential to become attracted to sport fishing, and the rural population has virtually no potential. The natural Swazi attitude towards fishing gives more priority to the food value than to the sport value. The upper and middle classes may pursue sport fishing in the future but this is not predictable.

Other recreational activities, such as boating, swimming, water-skiing, camping, picnicking, and hiking, could also benefit from an increase in reservoirs. Non-Swazis would, again, be expected to

account for the bulk of participation in these activities, at least in the near term.

Any of the activities mentioned, including fishing, would not be able to flourish where chances of schistosomiasis infection are high. Schistosomiasis control would have to be especially effective in the Middleveld and Lowveld regions to accommodate water-contact activities. Highveld region reservoirs could be sufficiently cold and free of snails; this would preclude schistosomiasis problems.

The references used in this section are 23, 31, 73, 76, and 77, as listed in Section T.

SECTION H

EXISTING AND PROPOSED PROTECTED AREAS

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SECTION H

EXISTING AND PROPOSED PROTECTED AREAS

Thirty-one areas have been selected by the Swaziland National Trust Commission for intended proclamation as protected areas. These areas would be managed as national parks, nature reserves, national landscapes, and national wetlands. The proposed areas would include or alter the five protected areas already existing in Swaziland. The five existing areas are shown in table H-1.

Table H-1
Existing Protected Areas

Name	Area (hectares)
Mlilwane Wildlife Sanctuary	4,545
Hlane Wildlife Sanctuary	14,219
Ndzindza Nature Reserve	5,503
Malolotja Nature Reserve	18,065
Mbabane Nature Reserve	321

The purposes for maintaining protected areas are to preserve representative examples of all Swaziland's major ecosystems, to protect habitat for endangered or threatened species, to perpetuate authentic African landscapes, and to preserve the Swazi heritage. Maintaining protected areas could also provide for hunting, employment, and educational activities.

Value categories are assigned according to these guidelines:

- A1 - Highest quality, supreme protection worthiness, wholly natural and unspoiled, with negligible intrusions.

- A2 - High quality, although with alien intrusions.

- A3 - Important, although degraded or created by intrusions; e.g., manmade reservoirs.

Priority ratings are assigned to indicate the urgency of protection resulting from the area's vulnerability to outside pressure. A1 areas may be somewhat self-protecting or in low danger of degradation. A3 areas are under high pressure and urgently need protection.

National park status would be assigned to areas of ". . . the highest conservation status which can be accorded . . ." (Reilly). No alternative land use would be tolerated. Nature reserve status would fall on areas meriting less absolute protection. Compatible alternative land use such as limited grazing could be allowed as long as conservation remained paramount. The legal status of nature reserves would also be granted to areas proposed as national landscapes and national wetlands. National landscapes would preserve esthetic beauty and represent the Swazi heritage. The areas by their nature may be self-protecting, but while use such as regulated grazing would be allowed, settlement would be forbidden. National wetlands would protect manmade waterbird habitat to replace the natural habitat lost in the past. They would accommodate the migrating waterbirds in their international travels and would, thus, be a multinational resource.

Altogether, these protected areas as proposed would cover 164,485 hectares (ha), which is 9.5 percent of Swaziland's land area. No change from present land use would be involved in 80.5 percent of the proposed area. Extensive resettlement would be required from Sibebe and Ndlotane national parks, as has already been achieved at Mlilwane and Malolotja reserves. The Sibebe and Ndlotane areas were both rated highest quality with highest vulnerability.

Other areas of particular interest in Swaziland are not proposed for protection because they are either heavily settled or are in great demand for other use. The 31 existing and proposed protected areas, their surface area, the value category, and the priority are presented in table H-2. These areas are illustrated on plate 4.

Table H-2
Existing and Proposed Protected Areas

Protected Areas		Approx. Area (ha)	Value Category	Priority
National Parks				
Area 1	Mlilwane	5,710	A3	1
Area 2	Hlane (including adjoining nature reserve on Malahleni: 7,630 ha)	24,700	A1	1
Area 3	Malolotja (including nature reserve at Hawane: 140 ha)	18,210	A1	1
Area 4	Ndzindza (including adjoining nature reserve areas: 6,770 ha)	31,140	A1	1
Area 5	Sibebe (incorporating portion of present Mbabane nature reserve)	3,320	A1	1
Area 6	Ndlotane	7,980	A1	1
Area 7	Mnyame	11,950	A1	1
Area 8	Nugudzeni	7,030	A1	1
		110,040		
Proposed Nature Reserves				
Area 9	Mkondo	3,030	A2	3
Area 10	Helehele	1,190	A1	3
Area 11	Jilobi Forest	1,340	A1	2
Area 12	Siteki Forest	1,850	A1	2
Area 13	Ntabamhloshane	30	A2	2
		7,440		
Proposed National Landscapes (to be proclaimed nature reserves)				
Area 14	Luhlokohlo	60	A2	2
Area 15	Ntungulu	8,900	A1	2
Area 16	Mdzimba	5,730	A1	2
Area 17	Sondeza	1,600	A2	1
Area 18	Makhonjwa	2,680	A1	3
Area 19	Bulembu	530	A1	3
Area 20	Ndzeleni	560	A1	3
Area 21	Mahamba	2,620	A1	3
Area 22	Nsongweni	1,030	A1	3
Area 23	Lubombo	12,790	A1	3
Area 24	Tulwane	1,310	A1	2
Area 25	Mliba	110	A1	3
Area 26	Mananga	1,610	A1	3
		39,530		

Table H-2 (Cont'd)
Existing and Proposed Protected Areas

Protected Areas		Water Only (ha)	Approx. Area (ha)	Value Category	Priority
Proposed National Wetlands (to be proclaimed nature reserves)					
Area 27	Matsapha	90	180	A3	1
Area 28	Pongola	490	870	A3	3
Area 29	Nyetane	260	400	A3	1
Area 30	Mnjoli	2,570	4,280	A3	1
Area 31	Tjaneni	730	1,730	A3	3
		4,140	7,460		

Source: Reilly, 1979

The references used in this section are 23, 51, and 76, as listed in Section T.

SECTION I

ECONOMIC BACKGROUND

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SECTION I
ECONOMIC BACKGROUND

The following paragraphs discuss Swaziland's economy, government revenue, government expenditures, employment and income, transportation, foreign trade, and mining. The sections on the economy, government revenues, and government expenditures are near verbatim excerpts from the Third National Development Plan. The other sections are compiled from a number of sources.

THE ECONOMY

Swaziland's first modern or nontraditional economic activity began about the end of World War II; this was the export of asbestos from Havelock, which is located in the northwest corner of the country. In the late 1940's, a large-scale afforestation program was begun at Piggs Peak and later extended to Usutu. A pulp mill and a saw mill were established at a later stage. The development of the citrus and sugar industries began in the late 1950's and the exploitation of iron ore deposits at Ngwenya followed in the early 1960's. Also during the 1960's, a hydroelectric powerplant was constructed at the confluence of the Great Usutu and Little Usutu rivers. Additional developments during the period up to 1973 were the expansion of the citrus and sugar industries, the establishment of the Matsapha industrial complex in 1964, the expansion of the tourist trade, and the mining of coal at Mpaka. Other mining and industrial projects were also established in the late 1960's.

The establishment of all the major industries has been abetted by an inflow of foreign capital. As most production is export-oriented, favorable trends in the world economy enabled Swaziland to achieve moderate export gains.

Corresponding with these developments, there was an upward surge in Swaziland's Gross Domestic Product (GDP) between the end of the 1960's and 1973. Reliable official national accounts depicting GDP at factor cost are available up to Fiscal Year 1972-73. GDP at market prices was developed for 1973-74. Detailed estimates were also developed for subsequent years. According to these estimates, GDP at factor cost rose from E102.7 million in 1972-73 to E245.0 million in 1976-77. This corresponds to a real growth rate of 7 percent per annum. GDP per capita of the resident population is calculated at E495 for 1976-77. Estimates of GDP for the years from 1972-73 to 1976-77 are shown in table I-1.

Swaziland's traditional agricultural sector directly supports about 70 percent of the population. It is mainly dependent on subsistence cropping and livestock raising. The modern sector is chiefly engaged in the production and processing of primary products for export. This sector is thought to constitute about 65 percent of GDP; pulp and paper produced by the Usutu Pulp Company alone is 17.7 percent of GDP.

GOVERNMENT REVENUE

Government revenue is dominated by two major taxes: Southern African Customs Union payments and income tax. These two taxes comprised about 80 percent of revenue in 1978-79. A third tax, the sugar

Table I-1
Gross Domestic Product, 1972-73 to 1976-77
(E million)

Product	1972-73[1]	1973-74[2]	1974-75[2]	1975-76[2]	1976-77[2]
Agriculture	31.6	38.6	50.0	61.1	75.5
Mining	2.4	5.9	7.4	8.5	9.9
Manufacturing	21.6	26.5	34.6	42.3	52.5
Construction	3.7	4.8	6.7	8.8	11.7
Community and Other Services	16.8	20.6	26.9	32.7	40.2
Other Sectors	24.0	28.6	36.2	44.4	55.2
GDP at Current Factor Cost	100.1	125.0	161.8	197.8	245.0
GDP at Constant 1977-78 Factor Cost	202.3	222.5	239.2	255.0	272.1

1/ Central Statistical Office, 1975 **Annual Statistical Bulletin**

2/ Ministry of Finance and Economic Planning Estimates

export levy, was an important source of revenue between 1974-75 and 1976-77, the period of very high sugar prices; it is expected to play a less important role in the future if the price stabilization objective of the International Sugar Agreement is realized.

Swaziland is a member of the Southern African Customs Union with Botswana, Lesotho, and the Republic of South Africa (RSA). Under an agreement, union members interchange goods duty-free within the common customs area, and Swaziland receives a share of the revenue that is paid into a common customs pool by nonmembers.

Payments from the Customs Union are made according to a complex formula which relates the revenue to imports that occurred 2 and 3 years previously; it also reflects changes in fiscal policies in South Africa. Thus, this revenue bears no direct relation to the current level of economic activity in Swaziland and the rate of revenue is outside the control of this government. The revenue can vary widely

from year to year, and this would be a destabilizing influence on the budget if reserves were inadequate to allow for these fluctuations.

Income tax revenue has shown continued strong growth; this reflects some recovery in company profits, a high growth rate of employment, and the effects of the progressive tax scale for individuals.

Other tax revenues are expected to show an increase in line with the growth in economic activity. Table I-2 presents recurrent revenues for available years.

Table I-2
Recurrent Government Revenues
1973 to 1979
(E million)

Source	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79
Income Taxes	10,731	10,544	21,049	20,389	24,440	18,782
Other Taxes 1/	15,821	29,607	44,485	27,982	50,114	61,868
Property and Interest	757	1,171	2,493	3,386	4,141	4,900
Sales of Goods and Services	714	589	586	801	1,075	835
Miscellaneous	570	2,802	896	1,774	1,388	1,054
Total	28,593	44,713	69,509	54,332	81,158	87,439

1/ Includes customs and excise tax

Source: Treasury Reports

GOVERNMENT EXPENDITURES

The government has generally been able to present a balanced budget. Table I-3 presents government expenditures for the past several

years. The government's Third National Development Plan, however, calls for a significant upgrading in government services and an ambitious building program. This will cause budget deficits ranging from E19 million to E74 million during the plan period. (Government objectives are to simultaneously increase revenues proportionately so that these deficits do not materialize.)

Table I-3
Government Expenditures
1973 to 1978
(E million)

Expenditures	1973-74	1974-75	1975-76	1976-77	1977-78
General Public Services	16,844	17,981	21,067	25,056	31,784
Housing and Community Development	842	1,104	2,000	2,288	2,789
Other Community and Social Services	121	306	609	398	297
Economic Services	4,428	7,870	8,396	8,802	10,422
Other	5,511	17,787	25,701	10,881	26,678
Total	27,746	45,048	57,773	47,425	71,970

Source: Treasury Reports

EMPLOYMENT

Employment in Swaziland falls under two categories. The first category is composed of employment in the modern or paid employment sector; the second category is the traditional or rural area sector.

Comprehensive unemployment figures are not available because the rural population is not differentiated into employed and unemployed.

An examination of employment projections in the Third National Development Plan for the modern sector indicated that the current urban unemployed number is from 20,000 to 30,000, which is about 10 percent of the working age population.

Swaziland's population growth will pose increasing demands on the job market in both the modern and rural sectors. Projections of the working age population are presented in table I-4.

Table I-4
Projections of Working Age Population
(1,000's)

Year	Male	Female	Total
1980	118.5	149.2	267.7
1985	138.3	174.0	312.3
2000	223.3	280.6	503.9
2030	416.8	523.8	940.6

Source: Office of Economic Planning

These projections are based on the assumption that the fertility rate would remain constant while the mortality rate would decline. This corresponds to the high projection presented in the Population Section.

Part of the objective of the current study is to determine whether irrigation development can provide rural sector employment for Swazis who are not absorbed by the modern sector. This depends partly on modern sector employment rates. Total modern sector employment for recent years is presented by activity in table I-5.

The Third National Development Plan estimated that by 1983 the modern employment sector (paid employment) would increase to 85,000

Table I-5
Paid Employment by Activity

Activity	Total Employees 1972	1975	1977
Agriculture and Forestry	24,332	28,666	26,377
Mining and Quarrying	2,950	3,079	3,086
Manufacturing	6,512	8,998	8,411
Electricity and Water	541	405	1,226
Construction	3,629	3,341	4,081
Distribution	3,842	4,519	5,516
Transportation	2,280	2,583	2,768
Finance and Business Services	580	1,187	1,477
Social Services	9,190	11,929	13,283
Total	53,856	64,707	66,225

Sources: 1978 Annual Statistical Bulletin; Third National Development Plan

workers. Assuming that this general rate of increase continues, the modern sector would employ 90,000 workers by 1985 and 125,000 workers by the year 2000.

The 1977 total modern sector employment figure represents about 27 percent of the total working age population (15 to 64 years). The remainder of the working age population consists of the self-employed, the unemployed, and a large population on Swazi Nation Land (SNL) engaged in subsistence agriculture. All of these groups can reasonably be classified in the rural sector, which would, therefore, comprise 73 percent of the working age population. In 1980, this percentage would represent 195,421 rural sector workers.

To determine how many rural sector jobs would be needed in future years for full employment, the projected modern sector employment can be substracted from the projected working age population. This is determined for the years 1980, 1985, and 2000 in table I-6.

Table I-6
Projected Rural Sector Employment Needs

Year	Working Age Population	-	Modern Sector Projection	=	Rural Sector Demand	Rural Increase Needed
1980	267,700	-	72,300	=	195,400	
1985	312,300	-	90,000	=	222,300	26,900
2000	503,900	-	125,000	=	378,900	156,600
					Total	183,500

In order to provide reasonably full employment, the rural area employment sector would have to absorb about 26,900 new workers by 1985 and an additional 156,600 new workers by the year 2000.

Employment data for existing and planned irrigation schemes within the country show that, on the average, 1 irrigated hectare (ha) requires a total of about 0.37 man-years of labor. The range of labor requirements for irrigated land is from 0.20 man-years per irrigated hectare for maize to 0.62 man-years per irrigated hectare for tomatoes. These figures are for the more capital intensive irrigation projects currently in existence or planned in Swaziland. It is estimated that labor requirements for irrigated land under labor intensive operations would be about 0.50 man-years per hectare.

Employment data for existing irrigation schemes also show that for every job created on the farm, two additional jobs are created in directly related sectors, such as farm management or food processing, or in indirectly related sectors, such as transportation. Therefore, about 1.5 man-years of work would be created for each new hectare brought under cultivation with irrigation.

It is not known how much work would be created by bringing a new hectare under cultivation without irrigation. It is, therefore, not known whether irrigation development would provide more employment than dryland development.

The two-to-one relationship for irrigation will tend to continue until the economy of Swaziland becomes more modern, consolidated, and efficient. Increased automation and other efficiencies would reduce the two-to-one ratio.

There are currently about 36,400 ha of irrigated land in Swaziland. Assuming that each new hectare of land brought into cultivation under irrigation creates 1.5 man-years of labor, the number of hectares needed to absorb the future rural labor demand can be projected. These projections are presented in table I-7.

Table I-7
Irrigated Area Needed to Absorb Future Rural Labor Demands

Year	Rural Labor Demand (man-years)	Irrigated Area Needed (ha)	Existing Irrigated Area (1980) (ha)	Increase Needed From 1980 (ha)	Increase Needed From 1980 (percent)
1980	195,400	130,000	36,400	-	-
1985	222,300	148,200	-	111,800	300
2000	378,900	252,600	-	216,200	700

INCOME

Table I-8 presents average monthly income by industry for the latest year available. Minimum wages in Swaziland are established on an industry-by-industry basis by industrywide wage councils. The councils are tripartite groups representing management, labor, and government.

Table I-8
Average Earnings by Skill and Sex
(E/month as of June 1977)

Industry	Professional		Administrative		Clerical		Skilled		Semiskilled		Unskilled	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Agriculture	723	270	565	- 1/	111	176	358	0	80	26	39	28
Forestry	741	0	397	-	127	-	262	0	89	-	48	25
Mining	967	270	833	-	170	182	530	0	148	120	95	90
Manufacturing	732	354	630	293	187	195	477	44	147	64	68	53
Construction	705	-	523	-	159	114	126	0	205	0	50	30
Distribution	535	439	476	283	166	104	218	136	91	41	72	57
Transportation	446	0	503	-	147	153	238	-	93	0	85	36
Finance	558	360	745	413	267	234	422	195	15	83	65	52
Social Services	369	179	515	331	109	97	346	154	100	73	57	25
Average - All Industries	654	243	572	308	173	166	345	154	122	49	53	35

1/ A very small number of employees

Source: Annual Survey of Employment

During the first half of the 1970's, increases in the nominal minimum wage rates exceeded the rise in the cost of living. In recent years, however, the trend has reversed and continued inflation has eroded much of the real growth in minimum wages.

Earnings shown in table I-8 are for the modern sector. Information on earnings in the traditional sector on SNL is not readily available.

TRANSPORTATION

ROADS

One of the primary considerations in the development of a marketing infrastructure in Swaziland is the development of an adequate road system. The current road system consists of 1,428 kilometers (km) of main roads and 1,225 km of district roads. The main roads connect the major centers of population and generally are all-weather roads. The majority of the main roads have either bituminous, sand-sealed, or gravel surfaces. The district roads serve as connectors to the main road system, although they are frequently impassable during wet weather conditions. District roads are usually gravel or earth-surfaced roads.

The main road system is generally adequate for the development of a marketing infrastructure. About 80 percent of the population of Swaziland is located within 5 km of a main road and nearly all of the population is within 10 km of a main road.

Road construction plans call for hard surfacing an additional 400 km of the main roads by 1983; more than 50 percent of the system will then be hard surfaced. The plans also call for the construction of an additional 400 km of district roads.

RAILROADS

Swaziland's original railway line was constructed to transport iron ore from the mine at Ngwenya to the Mozambique port of Lourenco Marques (now renamed Maputo). The line is 224 km long and has recently been used to transport other commodities, such as sugar, molasses, wood pulp, fruit, and coal. A new line was recently constructed to link the original line with a line in the RSA south of Lavumisa. A more recently proposed line would link the original line with a line in the RSA to the north of Manana. The transportation system is shown on plate 5.

FOREIGN TRADE

The foreign trade situation in Swaziland is typical of a developing country. Exports consist largely of raw products and imports consist of finished products, machinery, and fuels. The following paragraphs briefly explain the foreign trade situation.

EXPORTS

Swaziland's major exports are derived from the economic activities of sugar growing, forestry, and mining. These three sources of export products generally account for about 80 percent of total exports in any

given year. Other important export items include fruit and fruit products, cotton, and live animals and meat products.

The relative importance of major export commodities has changed considerably in recent years. Iron ore declined from 22 percent of total exports in 1971 to about 6 percent in 1977. Sugar and wood product export incomes have fluctuated widely because of changes in domestic production and international markets. The value of exports overall has shown steady growth, rising from a total of E39.3 million in 1968 to E143.1 million in 1977.

Swaziland's export markets are reasonably well diversified. About 90 percent of exports have destinations outside the southern African areas, mainly in Europe, North America, and Japan. The largest single market is the United Kingdom. Table I-9 presents the value of total exports for recent years and the percent of total value for major export commodities.

IMPORTS

The import commodities of major importance are machinery and equipment, fuels, chemicals, and manufactured articles. Food commodities, including food, live animals, and oils, represent a fairly significant proportion of total imports. This reflects the fact that the rate of population growth is outstripping the rate of growth in agriculture and food processing. The source of most of Swaziland's imports is the RSA. Table I-10 presents the value of total imports for recent years and the percent of total value for major import commodities.

TRADE BALANCE

From 1968 to 1975, Swaziland had an overall trade surplus. During 1976 and 1977, however, Swaziland had a trade deficit, as shown in table I-11.

Table I-9
Domestic Exports

Product	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Total Exports (E million)	39.3	44.5	50.3	55.1	61.8	72.8	119.6	143.7	157.0	143.1
Percent of Total:										
Sugarcane	23.1	23.6	23.5	20.9	31.1	27.6	40.2	56.6	35.3	38.1
Wood Products	13.7	16.0	19.1	17.4	18.0	28.9	30.7	13.5	23.7	19.8
Minerals	38.2	35.5	32.2	32.7	22.5	20.0	15.1	14.8	16.5	16.7
Fruit	6.1	9.7	8.9	9.8	8.4	9.4	6.1	5.6	6.3	9.3
Cotton	N.A.	N.A.	N.A.	N.A.	N.A.	3.8	0.9	4.0	3.0	5.3
Meat	5.8	2.9	3.4	3.8	3.6	5.8	3.8	2.1	3.8	3.4

Source: Central Statistical Office

Table I-10
Domestic Imports

Product	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Total Imports (E million)	34.1	37.4	42.7	47.8	53.3	66.6	93.4	131.6	174.1	194.8
Percent of Total:										
Machinery	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	24.7	26.0	30.9	20.0
Fuels	8.5	8.3	8.2	8.2	8.1	8.7	11.6	10.5	10.9	12.1
Manufactured Articles	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	26.2	20.8	19.5	19.0
Food	12.6	13.9	11.7	10.8	9.4	9.2	8.1	8.7	8.1	8.2
Chemicals	10.3	10.4	9.6	10.3	12.0	11.4	10.7	9.0	7.4	8.0

Source: Central Statistical Office

Table I-11
Visible Balance of Trade
(E million)

Year	Imports	Exports	Reexported Imports	Balance of Trade
1968	34.1	39.3	-	+ 5.2
1969	37.4	44.5	-	+ 7.1
1970	42.7	50.3	0.5	+ 8.1
1971	47.8	55.1	0.6	+ 7.9
1972	53.3	61.8	1.2	+ 9.7
1973	66.6	72.8	1.4	+ 7.6
1974	93.4	119.6	1.9	+28.1
1975	131.6	143.7	2.0	+14.1
1976	174.1	157.0	2.0	-17.1
1977	194.8	143.1	3.0	-48.7

Source: Central Statistical Office

Large import expenditures can be expected to continue as long as development in Swaziland continues to require large imports of machinery. As the country begins to export finished products, it may be able to compensate for the imports and avoid deficits.

MINING

The exploitable reserves of high- and medium-grade iron ore in Swaziland have been exhausted. The mining of asbestos began in 1939 and is expected to continue well into the 1980's and possibly longer. Now that the high- and medium-grade iron ore reserves have been exhausted, coal appears to be the mineral with the greatest future potential. To date, it has been mined only on a small scale, but recent explorations have indicated good quality reserves of at least 200 million tons.

Newly proven reserves of tin and kaolin offer possibilities for smaller scale mining and processing operations. There has also been some interest recently in the possible investigation of the old gold mining areas. Two diamondiferous areas have been discovered, but further investigation is required to determine whether exploitation would be feasible.

Geological mapping of the entire country, at a 1:50,000 scale, is due to be completed in 1980 and mapping of the coal field, at a 1:10,000 scale, is underway. Detailed mapping for specific mineral targets is in progress or has been completed; this mapping indicates new mineral findings which merit further study.

More direct government control in the exploitation of mineral resources has been achieved. Negotiations are in progress for increased participation by the Swazi Nation. Improvement of infrastructure at the mines and company towns by the mining companies has increased benefits to the Swazi people.

Coordination among the various interests involved in mineral development has continued, where possible, at a high level. This is particularly true concerning the development of a potential thermal power station, the new railway link to Lavumisa, and the proposed railway link to a line in the RSA. A ceramics factory and an iron smelting operation are also under consideration. It is apparent that guidelines for a national policy on the rate of depletion of the country's mineral reserves are needed.

The following paragraphs discuss the present situation concerning specific mineral products.

ASBESTOS

The present production amounts to 800,000 to 900,000 tons of ore per year to produce 36,000 tons of asbestos per year. The potential exists for extending mining operations beyond the physical boundaries currently specified in the mining lease. The asbestos mining company has embarked on an improvement program for the mine and the adjacent township; this program will improve the living and working conditions of the nearly 2,000 employees. Tighter dust control measures and regular medical checkups of all employees have been instituted.

IRON ORE

The potential exists for upgrading lower grade iron ore reserves for pelletizing, either for export or for internal consumption in a steel mill. There are considerable reserves of lower grade ore.

COAL

Coal is the mineral with the greatest future potential. It is likely to play a major role in the economy of the country in future years. The worldwide energy crisis has centered new interest on Swaziland's proven and potential deposits of high-grade coal. Should the four coal-bearing areas now being studied prove viable, four new coal mines could be established with a possible annual production in excess of 4 million tons. The largest of these areas alone could probably produce more than 2 million tons annually when in full production. A determination of the best potential domestic uses will be required. Until the internal demand for coal reaches the output potential of the proposed mines, export markets will be needed. The present production amounts to approximately 180,000 tons per year of which 30,000 tons are used locally and 150,000 tons are exported. Approximately 500 to 600 persons are employed at the existing mine at Mpaka.

OTHER MINERALS

Two diamond deposits have been discovered and explorations are continuing to determine whether they are economically viable.

Alluvial tin is being worked as a small-scale operation and there is the possibility, depending on the results of current investigations, that other areas may be similarly worked.

The abandoned gold mine at Piggs Peak may still have economic possibilities. The lower levels of the mine have been dewatered, mapped, and sampled. As a result, a private company has expressed an interest in obtaining prospecting rights.

Minor deposits of industrial minerals, barite, kaoline, pyrophyllite, silica, and ornamental stone have been investigated and appear to have economic potential. Large deposits of good quality ceramic and brick clays may be developed if economic conditions prove satisfactory.

The references used in this section are 18, 28, 29, 30, 31, 32, 33, 34, 74, and 76, as listed in Section T.

SECTION J

ENERGY

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SECTION J
ENERGY

The Swaziland Electricity Board (SEB) is responsible for the provision of all public supplies of electricity.

The SEB Edwaleni Hydroelectricity generating complex began in 1964 and now has four 2.5-megawatt (MW), one 5-MW, and one 6.5-MW hydropower generators. Two 4.5-MW diesel generators are also located at this complex. The hydroelectric generating capacity is fully used when water is available. Due to fuel costs, operation of the diesel generators is expensive and they are used for peakload operations only. Additional power requirements are purchased from the South African Electrical Supply Commission (ESCOM). These purchases began in 1973 and, in 1978, had grown to about 47 percent of total consumption.

An SEB national power grid now covers the entire country and electricity can be supplied anywhere in Swaziland. The firm upward trend in demand for electricity from the SEB national grid is continuing. The major growth areas are still the urban centers of Mbabane and Manzini. Increases in demand, however, have been apparent in many other areas. Expectations are that the growth in demand for electricity will continue.

Some large industrial concerns still generate a substantial part of their own requirements under license from the SEB. The major energy producers in Swaziland other than the SEB are the Havelock mine, Usutu Pulp Company, and the sugar mills of the Ubombo Ranches and the Mhlume Sugar Company. These producers are, however, connected to the SEB grid, and as production in these industries increases, more power is supplied to them by the SEB.

CONSUMPTION CATEGORIES

DOMESTIC

Domestic consumption has increased annually over the past 5 years. This increase is mainly due to increases in the numbers of consumers. Another contributing factor is consolidation of large rural areas and increased levels of rural electrification. Use of electrical appliances both in rural and in urban areas is also increasing.

COMMERCIAL AND INDUSTRIAL

Commercial and industrial consumption also increased in 4 of the last 5 years. As would be expected, this increase is due to growth in the size and number of these types of operations.

IRRIGATION

Irrigation consumption during 1979 increased at the Big Bend estates, Mhlume Sugar Company, and Tambukulu estates. The increases were due to expanded facilities and increased pumping requirements. Electricity was also supplied to the Royal Swaziland Sugar Corporation over the past year (1979). No increase occurred at the Ubombo Ranches or at the Swaziland Irrigation Scheme. Smaller consumers showed an overall increase.

DEMAND PROJECTIONS

Total sales for 1979 amounted to 222.8 gigawatt-hours (GWh). It is anticipated that future demands and, thus, future sales will increase at an even greater rate than the 10.7-percent rate increase of 1979. Estimates for 1980, 1981, and 1982 anticipate increases of 15, 19, and 15 percent, respectively. The forecast then calls for a gradual reduction in growth through the mid-1980's, followed by uniform growth rates of about 4 percent annually up to the year 1990. Total sales are expected to reach 256 GWh in 1980, 430 GWh in 1985, and 526 GWh in 1990.

In order to meet this increase in demand, the SEB is planning to construct the Luphohlo-Ezulwini Hydroelectric Scheme with an installed capacity of 28 MW. This amount will not, however, meet all the need, and additional power will be required to meet the forecasted loads. It is assumed that the additional requirements will be met by continued purchases from ESCOM. Swaziland may also build a coal-fired thermal plant near a mine source in the Lowveld region or additional hydropower facilities.

WATER BALANCE

Present water consumption is assumed to be minimal because the water used to generate the existing hydropower plants is returned to the river. The same condition will prevail even after the Luphohlo-Ezulwini Hydroelectric Scheme is put into operation. In the event a coal-fired thermal plant is constructed and water is used for cooling,

increased water consumption will occur. For a thermal plant of about 40 MW capacity, it is conservatively estimated that approximately 1.2 million cubic meters could be consumed annually. This includes the domestic and other related uses needed to accommodate a total facility.

The references used in this section are 4, 31, and 78, as listed in Section T.

SECTION K

GROUND WATER

SECTION K
GROUND WATER

Ground water is largely undeveloped as a water source in Swaziland. Urban and industrial water requirements are mainly drawn from surface water supplies. Although ground water is being used to supply some rural areas, most of the populace must draw water from surface supplies. There is a problem, especially in the Lowveld region, with a lack of consistent surface supplies. During the dry periods each year, people often have to walk several kilometers (km) to find a usable water source. The surface water, which is more accessible during the wet season, is a vehicle for waterborne diseases.

Some wells have been used to provide clean water for rural schools, clinics, and other public uses; the ability of these wells to supply a nearby community has been a fringe benefit. Frustrations, such as low-yielding boreholes, solid casing usually driven to solid rock, and pump maintenance problems, have discouraged the use of ground water.

Even though ground water resources have been considered unimportant in the past, the Ezulwini and Malkerns areas have a relatively high concentration of boreholes and the highest well yields. A good portion of the reported yields are approximately 4 cubic meters per hour.

In the past year (1979), several wells with slotted polyvinyl chloride casings have been installed by the Geological Surveys and Mines Department. These wells have reported yields of about 14 cubic meters per hour. Some of these wells were installed in areas where extremely low production or dry holes would have been expected in the past. The methods employed to establish these well sitings were geologic mapping, photogeological studies, actual ground investigations, and geophysical techniques. The Geological Surveys and Mines Department sited a number

of wells using similar techniques in the Makhosini area. The reported yields from this scheme range up to 14 cubic meters per hour. These yields present a definite potential source for domestic needs and could also have some potential for garden and livestock watering. Supplies for large-scale irrigation are inadequate; however, these supplies may provide the initial impetus to accelerate large-scale irrigation development but should not delay this development.

Swaziland has a very complex geology; in order to achieve the higher yields, a systematic program of geological investigations should be used to plan each well site. High-yield wells are generally located to penetrate zones of high fracturing near fault or shear zones. Locating wells to take advantage of this condition is very important. The Ezulwini and Malkerns areas are exceptions to these conditions. However, future wells should be located carefully so that excess withdrawal will not become a problem. Also of importance to this planning phase would be some type of legislation that would require a permit; all existing and future wells and boreholes would then be catalogued. The information contained in the existing catalogued borehole data file is of extremely limited value. If these data were used to estimate the extent of the ground water resource in a given area, only a crude approximation could be obtained and it would be subject to significant errors. Consequently, no attempt has been made to quantify these data for this report. Some gross figures are available in existing reports.

In summary, the present ground water production is limited to boreholes and to sporadic surface springs. The greatest ground water withdrawal is presently in the Ezulwini and Malkerns areas. More select well sites are being considered by the Geological Surveys and Mines Department. Any continued effort in this area will be of benefit to the rural communities. Additionally, the Havelock area is currently

using ground water beneficially. During drought situations, Swaziland's ground water resources could be of extreme value, and a strong program in ground water development should be pursued.

The references used in this section are 9, 11, 27, 44, and 76, as listed in Section T.

SECTION L

AGRICULTURAL LAND USE AND SOIL CAPABILITY

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AGRICULTURAL LAND USE AND SOIL CAPABILITY

LAND USE

The major land use in Swaziland is agriculture. This includes grazing, cultivation, and forestry. Agricultural activity occurs as two types, subsistence and cash cropping. Historically, subsistence cropping was practiced by Swazis on Swazi Nation Land (SNL) and cash cropping was practiced by expatriots on Freehold Title Land (FTL). Although this pattern exists today, it is changing as Swazis have begun to acquire land and to practice commercial agriculture. In addition, there has been considerable effort by the Swazi government to teach the Swazis cash cropping techniques for use on SNL. The Corps of Engineers' study is a part of that effort.

To date, the Swazi government's major program for increasing agricultural activity on SNL has been the Rural Development Area (RDA) Program. The primary intent of this program is to increase agricultural productivity and the general welfare of the rural population. Increased agricultural productivity is to be achieved through agricultural extension, soil conservation, and livestock improvement. Irrigation is put into effect wherever possible on a small scale and minor relocation of people is carried out where required.

There are 17 RDA's under development; these developments include approximately 60 percent of SNL. The ultimate goal is to bring RDA development to 100 percent of SNL. The RDA Program has not met with the success that was originally envisioned and it is being reevaluated by the government. The reasons for the lack of success are complex and

appear to be a combination of lack of social and cultural acceptance by the Swazi people and the inability of agriculture to compete economically with the urban job market. The resolution of these problems by the Swazi government is the key to the success of this national goal.

Approximately 66 percent (1,060,000 hectares (ha)) of Swaziland is devoted to some form of grazing activity. The majority of this occurs on land which has limited use for other agricultural pursuits. According to Murdoch, 520,000 ha is rock outcropping which has no agricultural use at all. Farmland and cropping activities, including forestry, account for another 20 percent (351,000 ha) and miscellaneous land use accounts for the remaining 14 percent.

Forestation and sugar plantations are the two major cultivation activities practiced on FTL. Cotton and maize are a distant third and fourth. On SNL, maize is by far the major cultivated crop and cotton is a distant second. Other crops grown in smaller amounts are groundnuts, beans, sorghum, potatoes, rice, pineapples, grapefruits, oranges, wheat, pecan nuts, tobacco, avocados, bananas, mangoes, naartjies, granadilla, tomatoes, lemons, and other miscellaneous vegetables.

RESEARCH

Research into the cultivation of these crops has not been consistently emphasized in the past and in recent years has been reduced considerably. Maize, sorghum, winter cereals, groundnuts, beans, soybeans, cotton, sunflowers, sesame, Irish potatoes, and sweet potatoes have all been tested to determine the best varieties, planting time, population and spacing, herbicides, and cultivation techniques. Fresh vegetables

tested for best varieties include carrots, cauliflower, cabbage, eggplant, peppers, onions, and tomatoes. Veld and pasture management techniques, nutrition, and plant introduction have been studied. The production suitability of rainfed and minimum irrigation crops has been studied in the Lowveld region. Various crops have also been tested to determine nutrient requirements for various soils. Soil and plant chemistry data have been obtained.

Studies have also been done to evaluate:

- the effects of soil structure on crop and pasture production;

- the techniques for optimum management of various soils;

- the control of disease for citrus, pineapples, cotton, rice, groundnuts, beans, gladioli, wheat, and vegetables; and

- the varieties of cotton, especially rainfed cotton, with high yield, high ginning percentages, and a lint quality suitable for South Africa processing.

Pests have been catalogued and their control has been studied for the major crops, especially citrus and cotton. Plans have also been made to reestablish the national insect collection. Biometry support in census and survey work and in design and field trials and biometry lectures at the University College of Swaziland have also been provided by the research stations. Forestry research and pineapple research have also been done at the Malkerns Research Station through the financial support of their respective industries.

Although the present program has been much reduced, research on the response of cotton and maize to pH control is still ongoing at Big Bend and at Malkerns Research Station, respectively. The United States

Agency for International Development (USAID) mission is establishing a research and extension project which will concentrate on the SNL farmer. Research stations will be at Malkerns and at the RDA's. Extension facilities will be at the Agricultural College at Malkerns.

SOILS

The soils of Swaziland are complex and, except for alluvial deposits, have developed in place over weathered parent material. Accordingly, they reflect the chemical properties of the parent material. In the Highveld, upper Middleveld, and Lebombo regions, the main soil types are deep, acid, and freely drained red and yellow ferrisolic and ferrallitic soils. Except for the Lebombo region, these soils have little natural fertility because of excessive leaching. With fertilization and lime application, however, these soils can produce high yields. These soils have drainage, infiltration, and moisture-holding properties which make them good for either dryland or irrigation use. Their limitation to cultivation occurs where the slopes are too steep or occasionally where the soils are too thin.

Soils in the lower Middleveld region are characteristically gray or red light-textured soils derived from granite or gneiss. Depth is normally between 40 and 70 centimeters (cm). The shallowness and light texture of the soils restrict available moisture-holding capacity for dryland cropping. They are generally low in fertility and highly erodible.

The western Lowveld region is underlain by sandstone and shale which have weathered to heavy-textured clay-pan soils. Poor drainage

and high salinity restrict their use for irrigation without considerable intensive management. Where these are overlain by poor moisture-holding light soils, their use for dryland cropping is also limited.

The eastern Lowveld region is underlain by basalt which has weathered to an association of red, brown, and black clays. A considerable portion, approximately 45 percent, is shallow--20 to 40 cm. Except for a shortage of phosphorus, the soils are quite fertile. The poor drainage properties of the black clays and their general high sodicity and salinity in low-lying areas limit their use for irrigation without intensive management. Given sufficient rainfall, however, they will produce good yields of cotton.

SOIL SUITABILITY

In a study by Murdoch, soils were divided into five classes of suitability for agricultural use. Table L-1 lists the five classes, their relative worth for agricultural purposes, and the number of hectares of each class in the major basins.

Within each soil suitability class identified in table L-1, there are a number of soil sets. Within each soil set are a number of soil series, each one composed of a single soil. Each series has similarities to other series in the set but also has characteristics distinctive from the other series in the set. The soil suitability symbol given for each class in table L-1 reflects the suitability value of the most common soil series in that class. Table L-2 gives characteristics of each soil and gives the suitability value for the crop mix of cotton, vegetables, rice, maize, and sugar that was used in the current study. While the data within the table are from Murdoch, any comments in the characteristics column which suggest alternative suitability ratings are a result of this study.

Table L-1
Soil Suitability by Class

Class	Hectares	Description
AS	163,000	High economic potential, no limitations on tillability
BS	113,000	Good economic potential, few limitations on tillability
CS	308,000	Limited economic potential, considerable management required
DS	365,000	Poor economic potential, extensive management required
ES	109,000	No economic potential for cultivation, some use as unimproved pasture

Murdoch based his soil suitability classes on soil type and slope. The classes were also based on suitability of the soil for a crop mix of maize, wheat, vegetables, cotton, and sugarcane.

Murdoch concluded that 100,000 ha could be intensively farmed and of this approximately 66,000 ha were irrigable. The 1970 United Nations Development Program (UNDP) Report identified just less than 50,000 ha as being irrigable. These two figures for irrigable land are relatively close and reflect the technical and economic constraints which determined the amount of irrigable land at that time. Because of improvements in agricultural technology and because the Swazi government is interested in pursuing irrigation on SNL from a social as well as an economic viewpoint, this study was able to assume fewer constraints in identifying potential irrigable lands.

IRRIGATION POTENTIAL

As a part of this study, it was necessary to determine the amount of soil which could be irrigated by the available water. This was done in two parts. The object of the first part was to identify the maximum amount of area which might conceivably be irrigated, disregarding any possible constraints. The soils and land capability study done by

Table L-2
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
AS	L			40,000		Red ferslalitic soil, good drainage, deep (100-200 cm), 3 percent of set has slope greater than 14 percent.
		AS	Lesibovu (Le)		19,800	Very deep, 200 cm plus, medium texture, low organic matter, some weathered minerals, drains too well for good rice production.
		AS	Lomahasheni (Lo)		10,500	Deep red clay-loam, higher in humus than other comparable soils, same constraint to rice production as above.
		BS	Lutzi (Lz)		5,700	Not as deep as others in series, weathered rock at 100 cm, hard rock at 170 cm, medium texture, unfit for rice.
		BS	Ludomba (Ld)		4,000	Similar to Le, gray-brown sand over red clay, no drainage problem despite two-deck nature, same rice problem as Le, slightly better than Lz.
	M			80,100		Deep red or orange kaolisol, 300 cm deep, low humus, minimum weatherable minerals, good drainage normally, 35 percent of set has slope greater than 14 percent.
		AS	Malkerns (Ma)		32,400	Red soil, medium texture, horizon of nutty structure at 30 to 80 cm.
		BS	Mtilane (Mt)		17,400	Red-brown, medium texture, thin quartz stoneline in top 90 cm over red loam.
		AS	Mooihoek (Mo)		10,500	Pale red, medium to light texture, sandy loam.
		AS	Mdutshane (Md)		7,700	Orange, medium to light texture, sandy loam surface over loam, permeable.
		AS	Mbeli (Mb)		4,900	Orange clay-loam, permeable.
		ES	Madeva (Mv)		4,000	Similar to Ma, but with large boulders scattered throughout making it unfit for cultivation.
		BS	Mzawo (Mz)		2,800	Gray sand, 20 to 50 cm deep, over Mt or Ma, permeable despite two-deck nature.
		BS	Munali (Mu)		400	Red or dark brown loam over clay, 20 to 40 cm, below which is deep red loam. Only soil in set good for rice.
	R			55,000		Brown or ferslalitic soils, dark red, moderate permeability, 2 percent of set has slope greater than 14 percent, heavy texture.
		AS	Rondspring (Ro)		27,100	Brown clay-loam, 50 to 100 cm to weathering rock, same to rock, can be too shallow.

Table L-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
AS (Cont'd)	R (Cont'd)	AS	Rathbone (Rt)		18,200	Brown clay, 180 cm deep, free lime below 90 cm, can have some drainage problems.
		AS	Rhebok (Rk)		6,100	Clay or clay-loam, soft iron pan below 60 to 100 cm, weathering rock by 140 cm, 22 percent of particles greater than 2 mm.
		BS	Rasbeni (Rs)		2,800	Brown soil, 60 to 90 cm of heavy texture soil over dark orange clay, impaired drainage.
		BS	Reidbult (Re)		800	Brown clay, 110 cm to weathering rock.
	W			9,700		Orange, brown, or red alluvium, 200 cm deep, low in humus, high in weathered minerals, medium to light texture, none of set has slope greater than 14 percent.
		AS	Winn (Wn)		6,900	Orange loam, free of cobbles, good drainage, best soil, can have nematode problems, not good for rice.
		BS	Waspageni (Wa)		1,200	Orange sandy loam over cobble bed, good drainage, 40 to 100 cm deep.
		CS	Wisselrode (Ws)		800	Brown loam or clay-loam, impaired drainage, high salt content, requires special drainage, should probably be rated DS without special management.
		BS	Whiterock (Wh)		800	Orange loam with white lime pan by 100 cm, moderately permeable.
BS	A			16,200		Deep yellow or yellow-brown ferralitic soil, imperfect drainage, 22 percent of set has slope greater than 14 percent.
		BS	Alicedale (Al)		6,500	Medium texture, soft iron pan below 100 cm, orange below that, very deep, 250 cm plus.
		BS	Amuke (Am)		5,200	Similar to Al, but without iron pan.
		CS	Atondozi (At)		4,500	Light textured gray-yellow soil over heavy subsoil with iron pan below 70 cm, marginal two-deck soil, without intensive management could be rated DS.
	CH			9,700		Red or dark brown ferralitic soil, 200 cm deep, moderately permeable, 42 percent of set has slope greater than 14 percent.
		BS	Coseni (Co)		6,100	Dark brown, blocky soil, very rich in humus, may require saline prevention actions, may be low in suitability.
		BS	Cimurphy (Cm)		3,600	Black top, 30 to 80 cm, over red subsoil, no more humic than Co, less blocky than Co, impaired drainage.

Table I-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
BS (Cont'd)	CL			39,300		Dark brown vertical, can have high organic matter content, imperfectly drained, high in weathered minerals, none of set has slope greater than 14 percent.
		BS	Canterbury (Ca)		29,600	Blocky clay, free lime below 20 cm, weathering rock below 60 to 90 cm, impaired drainage, calcareous.
	CH	BS	Cuba (Cu)		9,700	Similar to Ca without calcium carbonate.
	DL			2,800		Yellow or yellowish brown ferralitic soil, 150 cm deep, can have dark humic top, imperfectly drained, free lime in subsoil, none of set has slope greater than 14 percent.
		BS	Delcor (De)		2,000	Clay-loam with red and gray marbling, iron pan below 120 cm, need drainage management.
		AS	Daputi (Dt)		800	Sandy loam, soft iron pan below 120 cm, may be acid.
	F			13,000		Orange ferralitic soil, low humus, two decked but moderately permeable with soft iron pan, 9 percent of set has slope greater than 14 percent.
		BS	Felwaco (Fe)		5,300	Medium texture, iron pan at 60 to 100 cm, 20 percent of particles greater than 2 mm.
		AS	Funebizo (Fu)		5,300	Medium texture, iron pan at 120 cm, 25 percent of particles greater than 2 mm.
		CS	Frazer (Fr)		2,400	Sandy loam, weathered material by 60 cm, hard rock by 100 cm.
	NH			41,300		Yellow or red ferralitic soil, dark humic top, good drainage, 62 percent of set has slope greater than 14 percent.
		BS	Nduma (Nd)		30,000	300 cm deep, loam to clay-loam by 100 cm, too well drained for rice.
		CS	Ngazi (Nz)		11,300	Loam or sandy loam on weathering rock by 130 cm, this reddish orange subsoil just above rock. Would seem to warrant a higher rating.
	NL			2,800		Brown soil over red clay, good drainage despite two-decked nature, not humic, mapped with R set.
		BS	Nhloya (Nh)		2,400	Loam top over subsoil resembling Rp or Re, too well drained for rice, may be underrated.
		AS	Nsoko (Ns)		400	Alluvial accretion of Be or Wn over same subsoil as Nh, too well drained for rice.
	SH			34,000		Ferrisol, 120 cm or less (can be too shallow), dark humic top, good drainage, weathered minerals, 63 percent of set has slope greater than 14 percent.

Table L-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
BS (Cont'd)	SH (Cont'd)	BS	Sangweni (Sa)		26,300	Dark brown clay-loam, average depth of 100 cm to weathering rock, 20 percent of particles greater than 2 mm.
		CS	Sivulo (Sv)		7,700	Clay-loam with humic top, orangish layer above rock at average depth of 70 cm.
	TL			8,900		Dark gray or dark brown soil, moderately high organic matter, fairly heavy texture, none of set has slope greater than 14 percent.
		BS	Tambankulu (Tm)		6,500	Blocky clay over soft iron pan between 70 to 150 cm, then weathered basalt, no free lime, generally less suitable than BS rating due to shallow and drainage, 41 percent of particles greater than 2 mm.
		CS	Tshaneni (Ts)		1,600	Similar to Tm, but with heavy textured lenses, poorly drained, subsoil calcareous, same suitability comment as with Tm.
		BS	Thorburn (Th)		800	Fairly deep clay-loam, mottled orange below 60 cm, impaired drainage, same suitability concern as with Tm.
CS	B			20,200		Pale yellowish brown or brown alluvium, deep, low in humus, layered because of deposition, high in weathered minerals, 2 percent of set has slope greater than 14 percent.
		CS	Bushbaby (Bu)		13,800	Yellow-brown loamy sand top, heavy lenses, high sand, high permeability, too much so for rice, would seem to deserve higher rating under irrigation.
		AS	Betusile (Be)		4,000	Brown sandy with much fine sand, thin strata of light texture below 40 cm, good drainage, rates as a low AS.
		ES	Bona (Bo)		2,400	Pale brown medium to coarse sand, more subject to flooding, highly permeable, would seem to deserve higher rating under irrigation and fertilization.
	JH			37,200		Dark compact top on thick stone lime 30 to 60 cm deep over deep red soil or saprolite, moderate humus, slightly impaired drainage, 43 percent of set has slope greater than 14 percent.
		CS	Juweel (Ju)		22,300	Medium texture above and below stoneline at 30 to 60 cm, slightly impaired drainage, would seem to deserve higher rating.
		CS	Jolubela (Jb)		11,300	Similar to Jw but with thicker stoneline, gravelly loam texture in horizons, and weathered rock for subsoil, same rating concern as above.

Table L-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set		Soil Series		Area (hectares)		
Suitability	Symbol	Suitability	Name	Set	Series	Characteristics
CS (Cont'd)	JH (Cont'd)	CS	Johannesloop (Jh)		3,600	Dark brown loam top, clay derived from shale often below stoneline, same rating concern as above.
	JL			18,200		Ferralitic soil, 150 cm deep, low humus, weak structure, often colluvial, good drainage, none of set with slope greater than 14 percent.
		CS	Jovane (Jv)		10,100	Reddish gray gravelly sand, rates low CS, would seem to deserve high suitability rating.
		CS	Jekhi (Jk)		8,100	Gray-brown sandy loam, similar to Or, becoming orange by 60 to 70 cm, high in coarse sand, rated low CS, would seem to deserve better.
	O			86,600		Gray or red-brown, shallow, low in humus, rapid drainage, 30 percent of set has slope greater than 14 percent.
		CS	Orrin (Or)		70,000	Gray-brown, light to medium texture, 90 cm deep on weathered rock to 200 cm, Middleveld, absent in Lowveld.
		CS	Outspan (Ou)		16,600	Reddish brown loam sand, more humic than rest of set, Lubombo, rated a low CS.
	P			31,200		Lithosol to sol lessive or mineral hydromorphic soil, two decked with mottled layer thinner and coarser than H or ZL sets, shallow, low humus, imperfect drainage with occasional perched water table, 14 percent of set has slope greater than 14 percent.
		CS	Pofane (Po)		16,200	Gray sand to loam, 30 cm deep, gradual change to unaltered rock, Middleveld.
		DS	Petronella (Pt)		9,300	Similar to Po for 30 cm, then on thin pan of dark loamy clay.
		DS	Peebles (Pb)		5,700	Brown sandy loam on stoneline, over mottled heavy material and clay enriched weathered rock, western Lowveld, would seem to rate higher.
	SL			119,400		Dark lithosol, 40 cm maximum depth over similar depth of weathered parent material, moderate humus, high in weathered minerals, good drainage, considerable gravel and stone, 6 percent of set has slope greater than 14 percent. All these soils may deserve a higher rating.
		CS	Somerling (So)		86,200	Dark brown loam over rock, 35 cm maximum depth to weathering rock of same depth, 16 percent of particles are greater than 2 mm, slightly calcareous, good except for depth limiting, use reflects BS rating.
		CS	Sikhutwane (Sk)		12,200	Dark red soil, not always calcareous, depth similar to So, most limiting of SL soils.

Table L-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
CS (Cont'd)	SL (Cont'd)	CS	Stegi (St)		11,700	Dark brown loam to clay-loam, unaltered rock by 40 cm, no free lime present.
		CS	Shebani (Sh)		5,700	Black loam to clay-loam, calcareous on hard lime pan, fractured so drainage not impaired.
		CS	Spekboom (Sp)		3,600	Black loam to clay-loam, more acid than So at surface, calcareous by 30 cm. Should be listed with SH soils.
	ZH			9,700		Red or red-orange kaolisol, probably ferralitic, low humus, permeable, 79 percent of set has slope greater than 14 percent.
		BS	Zombode (Zo)		6,900	Red clay-loam, weathered rock by 90 cm, rates as a low BS, Highveld, upper Middleveld.
		BS	Zayifu (Za)		2,800	Orange clay-loam, otherwise same as Zo.
DS	E			20,200		Regosol, two-decked gray sand over clay or iron pan, top layer 90 cm deep, low humus, 2 percent of set has slope greater than 14 percent.
		DS	Enkulunyo (Ek)		12,500	Deep sand, rapid drainage, Lowveld, may be rated too low for good sprinkler irrigation.
		ES	Empahli (Em)		6,100	Marsh margins, pale gray top over wet sand before pan is reached, may be rated higher if subsurface drainage is put in.
		ES	Ebede (Eb)		1,600	Gravelly sand, moderately deep, similar to Ek, would seem to deserve same rating as Ek.
	G			29,100		Two decked, top layer 80 cm deep, buried hard iron concretions and cemented iron pan, not humic, mottled material beneath pan, 8 percent of set has slope greater than 14 percent.
		CS	Gocuka (Gc)		12,900	Grayish light texture on hard iron pan, impaired drainage, western Lowveld and Middleveld.
		ES	Gongola (Gn)		5,700	Hard iron pan at or near surface, may be higher rating if iron pan is broken up.
		CS	Gege (Ge)		4,500	Dark gray light texture top, most humic and acidic in set, impaired drainage, low CS rating, Highveld.
		DS	Gubane (Gb)		3,200	Pale gray gravelly sand on fragmented hard iron pan, rapid drainage, low organic content, may deserve higher rating, lower Middleveld.
		CS	Gudzeni (Gz)		2,000	Orange or red, medium texture, drainage slightly impaired, upper Middleveld.
		DS	Groening (Gr)		800	Orange or red counterpart to Gc, lighter top than Gz, impaired drainage, Lubombo, would appear to deserve a higher rating.

Table L-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
DS (Cont'd)	H			87,400		Sol lessive, light texture top over mottled sandy clay, not humic, lime in clay pan, poorly drained, 1 percent of set has slope greater than 14 percent.
		DS	Habelo (Ha)		45,300	Gray loamy sand over gray-yellow blotched sandy clay, 30 to 60 cm above pan, stones common, perched water table, would be rated higher with subsurface drainage.
		DS	Hlunya (Hl)		27,500	Yellow-gray top, similar to Ha with less stony sandy clay pan and poorer underdrainage, same rating comment as Ha.
		CS	Homestead (Ho)		8,900	Gray loam horizon at 50 to 70 cm, olive drab sandy clay pan at 100 cm, calcareous.
		DS	Hersov (He)		5,700	Pinkish gray sandy loam on sandy clay, red mottles in top 60 cm, below that is similar to Ha, Lowveld, would be rated higher with underdrainage.
	K			28,300		Black vertisol, cracking clay, 50 to 100 cm deep, medium humus, poor drainage, 1 percent of set has slope greater than 14 percent.
		DS	Kwezi (Kz)		24,300	Calcareous, weak granular surface, merges with olive drab horizon over weathering rock, Lowveld, can rate higher with good underdrainage.
		DS	King (Kn)		2,400	Slightly acid to 70 cm where calcareous band exists, Middleveld, similar rating comment as Kz.
		DS	Kwamtusse (Kt)		1,600	Calcareous with unbroken lime pan in subsoil, Lowveld, same rating comment as Kz.
	O			143,700		Gray, yellow, brown, orange, or red; shallow, 40 cm deep, rapid drainage, low humus, 30 percent of set has slope greater than 14 percent.
		DS	Otandweni (Ot)		89,000	Gray sand or loamy sand, high in coarse elements, very shallow, hard rock by 30 cm, western Lowveld.
		DS	Oldreef (Ol)		19,400	Yellow-gray loamy sand, Highveld only, more acid.
		DS	Ongeluk (Ok)		14,600	Orange or red loam, southern Highveld, would seem to deserve higher rating.
		DS	Omhlandlu (Om)		13,000	Yellow or orange, light to medium texture, high in fine sand, deeper than most in set, Lowveld, may deserve higher rating.
		DS	Osaguleni (Os)		7,700	Reddish sandy loam, truncated L set, western Lowveld, would seem to deserve higher since L set is rated AS.
	QH			59,100		Ferralitic soil, 120 cm deep, gravelly loam, low in humus, rapidly drained, 57 percent of set has slope greater than 14 percent.

Table I-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set		Soil Series		Area (hectares)		
Suitability	Symbol	Suitability	Name	Set	Series	Characteristics
DS (Cont'd)	QH (Cont'd)	DS	Qolweni (Qo)		47,400	Gray surface, red fine earth in subsoil, with red weathering rock, Highveld, upper Middleveld, would seem to have potential for higher suitability.
		DS	Qwabise (Qb)		11,700	Gray surface, orange-yellow in subsurface with weathering rock, same rating question as Qo.
	TH			47,300		Ferralitic soil to Regosol, shallow sandy loam on soft rock, weathered to great depth, medium humus, rapid drainage, 85 percent of set has slope greater than 14 percent.
		DS	Tateni (Tx)		42,500	Reddish gray loam-sand streaked with white kaolinite, 50 to 80 cm deep, would appear to rate at least a CS.
		DS	Torgyle (To)		4,800	Yellow-gray over yellow-orange weathered rock, same suitability question as with Tx.
	V			12,100		Dark vertisol, 150 cm deep, cracking clay, low humus, long and narrow strips, none of set has slope greater than 14 percent.
		DS	Valumgwaco (Va)		6,100	Black with free lime throughout, greatest enrichment in olive drab zone where calcareous, eastern Lowveld, generally not considered suitable for irrigation.
		DS	Vimy (Vm)		4,400	Dark brown over reddish subsoil below 60 to 80 cm, free lime throughout, saline/alkaline, Lowveld, rated low DS, generally unsuitable for irrigation.
		DS	Vuso (Vu)		1,600	Black, top 50 to 60 cm free of lime, then calcareous, generally unsuitable for irrigation.
	ZL			75,700		Dark sandy clay over olive drab silty clay, low humus, saline, poor drainage, none of set has slope greater than 14 percent.
		DS	Zwide (Zd)		49,800	Gray sandy loam 30 cm deep over sandy clay 110 to 150 cm deep, swelling of bottom horizon causes root damage, calcareous, considered unsuitable for all but pasture.
		CS	Zwakela (Zl)		14,200	20 cm or less of light top, 60 to 80 cm deep, not calcareous, better underdrainage than rest of set.
		ES	Zikane (Zn)		10,100	300 cm deep, light top sometimes absent, in gully-washed bottom lands, root problems, water logged, could be rated higher if drained properly.
		DS	Zebra (Ze)		1,600	Pale brown sandy loam, wash of B set, same as Zd but lower, adjacent to alluvial areas.
ES	DH			4,900		Black, very acidic organic soils, 67 percent of set has slope greater than 14 percent.
		ES	Darketown (Dk)		3,300	Mountain and hill peat, shallow, sandy, rapid permeability, very acid.

Table I-2 (Cont'd)
Suitability and Characteristics of Swaziland Soils

Soil Set Suitability	Soil Set Symbol	Soil Series Suitability	Soil Series Name	Area (hectares) Set	Area (hectares) Series	Characteristics
ES (Cont'd)	DH (Cont'd)	ES	Dziva (Dz)		1,600	Fen peat, sandy clay, poorly drained, very acid.
	I			35,600		Hydromorphic soil, stratified with dark humic top in ill-drained wetlands, alluvium, 15 percent of set has slope greater than 14 percent.
		ES	Idukathole (Id)		18,200	Light texture in top 50 to 120 cm, then medium to heavy, no free lime, Highveld and Middleveld, would appear to have some use if underdrained, good rice.
		ES	Imbojane (Im)		1,200	Clay on dried wetlands, calcareous, Lowveld, same suitability question as above.
		ES	Ingoje (In)		15,800	Medium to heavy texture, least clay in top, more organic that rest of set, no free lime, Highveld and Middleveld, good rice, appears useful for other crops if underdrained.
		ES	Ivy (Iv)		400	Gravelly clay, old delta, calcareous, same suitability question.
	QL			400		Solonetz; two decked, similar to Hlunya (H set), alkaline top over very alkaline sandy clay bottom, low humus, poorly drained, mapped with H set.
		ES	Qualm (Qu)		400	Yellow-gray with fine sand, high in salts, mapped with H, may be rated too low.
	U			517,200		Bare rock, surface must be at least 15 percent rock, 87 percent of set has slope greater than 14 percent.
		ES	Ungabolima (Um)		330,800	Hard rock, skirts of mesas, escarpment faces, etc., mostly acid and intermediate rocks.
		ES	Upcountry (Uc)		160,000	Unconsolidated debris and weathered rock, considerable deep soil around rocks.
		ES	Umbeluzi (Ub)		26,400	Valley floor rock bars, waterfalls or cascades, small pockets of drift or colluvial/alluvial soils.
	X			2,800		Active coarse flood plain alluvium, none of set has slope greater than 14 percent.
		ES	Xulwane (Xu)		2,800	White or pale brown gravels, active flood plain alluvium, could have beneficial use depending on flood frequency.
	Y			800		Saline soil, calcareous and sodic clay, 120 cm deep, no permeability, small flat depressions, none of set has slope greater than 14 percent.
		ES	Youngsvlet (Yo)		400	Dark brown with white saline in top 50 cm, results from poor irrigation, reversible with underdrainage, would have higher rating if restorated.
		ES	Yakeni (Ya)		400	Dark gray and mottled, alluvium, adjacent to IV which has been irrigated, acid top, calcareous below 90 cm, same suitability comment as for Yo.

Murdoch in the late 1960's was the basis for this study. The object of the second part of the study was to identify more exactly the areas which could practicably be irrigated given likely constraints. The second part also identifies the possible soil limitations in these areas and some of the management practices which may be required to make these areas productive.

Murdoch's study was essentially a soil reconnaissance with some detailed and semidetailed survey information shown where available. Although it is an excellent tool for preliminary planning, it has limitations for use in detailed planning for intensive agricultural use. A first order for further planning of any projects resulting from this study should be to have detailed soil surveys conducted. There is also a need for laboratory work as reliable data on the physical, chemical, and mineralogical properties of the country's soils are limited.

In order to maximize the amount of land considered as potentially irrigable during the first phase of the study, some assumptions were made regarding water availability, methods of irrigation, and slope and tillability of soils. Regarding water availability, it was assumed that there is an unlimited supply and that it could be diverted to the irrigable land by either gravity channels or pumping. It was also assumed that a suitable irrigation method was available to irrigate all soils which were identified. It was further assumed that soils with slopes as great as 14 percent could be irrigated and that most soils could be irrigated if intensively managed.

The second part refined these assumptions in order to identify more accurately soils which were practicably irrigable according to water availability and land suitability. For water availability, diversion points were identified for the major areas and gravity canals were laid out. The tillability of the soil was considered and it was assumed that the most likely method of irrigation would be labor-intensive, riser-type sprinkler irrigation.

IRRIGABLE SOILS

LOMATI

There are approximately 18,000 ha of irrigable soils in the Lomati basin. On the left bank of the Lomati river, there are approximately 6,000 ha of good soil which could be irrigated. The soils here are predominantly Lesibovu and Lutzi from the L set, Orrin from the O set, and some from the M set. These range from average to excellent and represent the best soils in the Lomati basin. Approximately 400 ha in this area have some drainage problems and would require some subsurface drainage controls. Table L-2 shows the specific characteristics.

On the right bank of the Lomati river, there are approximately 12,000 ha of fair to excellent soil which could be irrigated. About 4,300 ha have some drainage problems and would require special control. Those soils requiring control are predominantly Empahli from the E set, some from the H set, Orrin from the O set, and Lesibovu and Lutzi from the L set.

KOMATI

There are approximately 47,000 ha of fair to excellent soil which have some suitability for irrigation in the Komati basin. The majority of these would require some drainage control. The predominant soils are Enkulunyo from the E set, some from the H set, and some from the ZL set. All of these would require some form of drainage control. The best soils are found immediately adjacent to the Komati river in the Lowveld region and are from the L set.

MBULUZI

There are approximately 31,000 ha of irrigable soils in the Mbuluzi basin. Downstream from the newly constructed Mnjoli dam, there are approximately 27,000 ha which are irrigable. Of these, 20,000 ha are on

the right bank and 7,000 ha are on the left bank of the Mbuluzi river. The predominant soils on the right bank are from the H and ZL sets. Both of these sets would require some drainage control. Of the 20,000 ha, approximately 12,500 ha would require some drainage control measures. The 7,000 ha on the left bank are mostly H and ZL set soils and would require drainage control.

LOWER USUTU

Of the approximate 37,700 ha of soils which are irrigable in the Lower Usutu basin, 18,200 ha were identified in the 1970 UNDP Report as the first and second phases of the Mapobeni area, Big Bend North, and Big Bend South irrigation schemes.

Of the remaining 19,500 ha, 15,500 ha are on the left bank of the Usutu river and 4,000 ha are on the right bank, south of the Mhlatuze river. The left-bank soils are predominantly from the ZL, SL, and O sets. The ZL soils require drainage controls and the SL and O soils are frequently too shallow for many crops. Of the 15,500 ha on the left bank, some 7,000 ha would require drainage control. The soils on the right bank are predominantly from the H, SL, and R sets. The R soils have few limitations to agricultural production. The H soils would require drainage control while the SL soils, as previously mentioned, can have depth limitations.

UPPER USUTU

In the Upper Usutu basin, which includes the Little Usutu, the Ngwempisi, and the Mkondo rivers, as well as the Upper Great Usutu river, there are approximately 36,000 ha of soils which are irrigable. Most of these occur in small blocks of generally good to excellent soil immediately adjacent to the river. The exception to this is the land north of the Malkerns area where a fairly large block, 13,000 ha, of excellent soil exists along the Mtilane, Mbabane, and Little Usutu rivers. Most of these areas could be irrigated from small pumping systems.

NGWAVUMA AND PONGOLA

There are approximately 28,000 ha of soils which are irrigable in the Ngwavuma and Pongola basins. The soils are mostly from the R, SL, CL, and K sets. With the exception of the K soils, which would require considerable drainage control, these soils rate good to excellent for agricultural productivity. As such, this area provides the largest block of quality soils of any area studied for potential irrigation. Although they are rated high, both R and CL soils can have drainage problems and may need some drainage control. Of the 20,000 ha below Damsite V, some 8,500 ha could require drainage control.

METHODS OF IRRIGATION

Three methods of irrigation were identified; these were furrow, sprinkler, and drip. Only the furrow and sprinkler methods were looked at in detail. Although drip irrigation is the most water efficient, it is generally limited to citrus-type agriculture at this time. If technological advances make it more feasible in the future, it should be looked at more closely because of its water efficiency.

Furrow irrigation normally requires more land preparation than sprinkler irrigation because of leveling requirements. Slopes, accordingly, must be flatter. Unless the sprinkler system involves pipe moving, furrow irrigation is more labor intensive. Furrow irrigation generally requires more water than sprinkler irrigation because of seepage losses, even though sprinkler irrigation can have high evaporation losses. Sprinkler irrigation requires a considerable investment in equipment. This cost can be reduced if the system is designed to be labor intensive--requiring much pipe moving. Sprinkler irrigation requires a greater power consumption than furrow irrigation because of the need to keep the system under pressure. If sprinkler irrigation is

pursued as a result of this study, supplemental hydropower should be considered as a means of providing the power to run the sprinkler system.

The references used in this section are 2, 21, and 51, as listed in Section T.

SECTION M

INTERNATIONAL CONSIDERATIONS

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SECTION M
INTERNATIONAL CONSIDERATIONS

NEGOTIATIONS AND AGREEMENTS

All of the main rivers in Swaziland arise in a neighboring country or depart into a neighboring country, or both. Thus, the Republic of South Africa (RSA), Swaziland, and Mozambique all share interests in the rivers, in the uses of the waters by their neighbors, and in the flows available after upstream uses. Negotiations among the three countries to apportion the water in these rivers of common interest began in 1967. These negotiations have continued in the form of tripartite technical discussions, bipartite technical subcommittee work, and numerous diplomatic notes and memorandums. Certain standards have been established, much information has been exchanged, and an agreement on flow apportionment of the Mbuluzi river was reached in 1976 with Mozambique. In 1973, an agreement mutually developed by the RSA and Swaziland was considered. The proposed agreement, however, was never ratified by the governments, and in 1976 the RSA found major portions of the proposal unacceptable and suggested fundamental changes which are unacceptable to Swaziland.

Since the initiation of negotiations, the RSA has constructed five major dams on these international rivers and is proposing the construction of seven additional dams. The reservoirs created by these dams provide cooling water for large coal-fired electric power generators and regulate flow for irrigation. The RSA is currently releasing water from existing reservoirs on the Komati river to maintain flows across the border. The RSA has expressed a willingness to negotiate releases

from existing and any future reservoirs. The basis for determining these releases and, therefore, the actual quantity and timing of these releases is still being discussed.

RSA DEVELOPMENT PLANS

Existing and proposed RSA dams are shown on plate 9. Abstraction records for existing dams were available from the RSA. The location, size, and estimated abstraction needs for proposed dams were available from the RSA report entitled "Possible Future Development in the Republic of South Africa of the Rivers of Common Interest with the Kingdom of Swaziland," 1980. In this development plan, the RSA proposes to reserve a specified annual flow for Swaziland. An analysis of the existing and planned abstractions indicated that in many cases the potential abstractions could be considerably larger. The Supply-Demand Analysis, therefore, examined the effects on Swaziland riverflows with the planned RSA abstractions and with maximum practicable RSA abstractions. Maximum practicable abstractions are defined as the abstractions that could be made, using the current RSA average monthly distribution of abstractions, that would result in a shortage index of 0.25, as defined in the Supply-Demand Analysis, while still providing the proposed Swaziland reserve.

LOMATI BASIN

The Lomati river arises in an afforested high rainfall area in the RSA, flows through Swaziland, and discharges back into the RSA where it

joins the Komati river. The only Lomati abstraction in the RSA upstream from Swaziland is for the city of Barberton. The abstraction is small and no future abstractions of significant quantity are anticipated in the RSA upstream from Swaziland.

There is no agreement on the flows that must be discharged to the RSA and no such border flow requirements are assumed in the current study. Although the RSA does assert a claim to its fair share of the Lomati river flows, it has not determined the volume or definition of that fair-share flow. The RSA does, however, plan to construct Driekoppies dam on the Lomati river downstream from Swaziland to provide a yield of 135 million cubic meters (mcm) per year for use in the RSA, utilizing existing flows from Swaziland. No downstream border requirements are included in this study and, therefore, flows could not be guaranteed to the RSA without a proportionate reduction in Swaziland's potential irrigation development.

KOMATI BASIN

The Komati river also arises in the RSA, flows through Swaziland, and discharges back into the RSA. The RSA has constructed two dams (Nooitgedacht and Vygeboom) on the Komati river since the initiation of negotiations. An additional dam, Hooggenoeg, has been proposed. The reported storage capacities of both Nooitgedacht and Vygeboom are 79 mcm. If constructed as proposed, Hooggenoeg would have a storage capacity of 484 mcm. With these three dams in operation, the RSA proposes to reserve an annual flow for Swaziland of 65 mcm. There is no agreement to guarantee Komati river flows back to the RSA. Data indicate that there is a court order requiring the release of 1.14 cubic meters per second at the Swaziland Irrigation Scheme (SIS)

diversion weir. The RSA has suggested ". . . that the South African share of the dry weather flow of the Komati River where it enters South Africa again from Swaziland shall provisionally and without prejudice be accepted to be equal to 1.5 cubic meters per second." In its latest development plan, the RSA proposes to construct Tonga dam about 30 km downstream from Swaziland to provide a dependable yield of 205 mcm per year for use in the RSA. No mention is made in the RSA plan of the expected flows from Swaziland, however, and, in this report, continuation of the 1.14 cubic meters per second release from the SIS diversion weir has been assumed for future downstream requirements. It is also assumed that this release must be passed through Swaziland, with no other withdrawals, to the downstream border with the RSA.

MBULUZI BASIN

The Black Mbuluzi and White Mbuluzi rivers both arise in Swaziland. They join to form the Mbuluzi river which discharges into Mozambique. A 1976 agreement between Swaziland and Mozambique requires that the flow at the border be equal to 40 percent of the flow at gage 3 on the Black Mbuluzi river plus 40 percent of the flow at gage 10 on the White Mbuluzi river. It is assumed that this requirement will continue.

USUTU BASIN

The Little Usutu river arises in the RSA and discharges into the Great Usutu river in Swaziland. Only a small portion of the catchment

is in the RSA and there are no proposed abstractions by the RSA. Swaziland is currently pursuing a written assurance from the RSA that it will not make any abstractions in the future. This assurance is required to guarantee power benefits for the proposed Luphohlo-Ezulwini Hydroelectric Scheme in Swaziland.

The Upper Great Usutu river also arises in the RSA. Since the negotiations began, the RSA has constructed Westoe dam and it proposes to construct Busby dam on the Mpuluzi river, a tributary to the Upper Great Usutu river. Westoe dam has a storage capacity of 60 mcm and the storage capacity of the proposed Busby dam would be 70 mcm.

The RSA and Swaziland have jointly examined the potential of a dam on the Mpuluzi river at the border between the two countries. This study analyzed this potential damsite and has determined that a dam with a storage capacity of 140 mcm would be capable of providing a dependable yield of 77 mcm per year. This dam could be jointly developed by the two countries.

The Ngwempisi river arises in the RSA and discharges into the Great Usutu river in Swaziland. The RSA has constructed Jericho and Morgenstond dams. Jericho has a storage capacity of 60 mcm and Morgenstond has a capacity of 114 mcm. Three additional dams are proposed by the RSA--Merriekloof on the Ngwempisi river and Watervaldrift and Ishlelo on the Hlelo river. The Hlelo river joins the Ngwempisi river in Swaziland. The combined storage capacity of these three proposed reservoirs would be 380 mcm.

The Mkondo river arises in the RSA and discharges into the Great Usutu river in Swaziland. The RSA has not constructed any dams on this river but does propose the construction of Heyshope and DeKraalen dams. The combined storage capacity of these two dams would be 740 mcm.

The Lower Great Usutu river is formed by the Little Usutu, Upper Great Usutu, Ngwempisi, and Mkondo rivers. Existing and proposed reservoirs in the RSA on these tributaries affect and will affect the flows in the Lower Great Usutu river. There are no agreements on releases from either the existing or proposed reservoirs; however, in its development plan, the RSA proposes to reserve the following release flows if the proposed RSA dams are constructed: Upper Great Usutu - 6 mcm, Ngwempisi - 15 mcm, and Mkondo - 28 mcm. The Great Usutu river discharges into the RSA, where it forms the border between Swaziland and the RSA for approximately 12 kilometers (km) and then forms the border between the RSA and Mozambique for approximately 24 km. It then joins the Pongola river to form the Maputo river which discharges through Mozambique to the Indian Ocean. There are no agreements on Great Usutu river discharges from Swaziland. The RSA does assert a claim to its fair share of the low flows. It has not defined what that flow is or how it should be determined. No downstream border requirements were mentioned in the latest RSA development plan and, therefore, none have been assumed in the present study. Flows could not be guaranteed to the RSA without a reduction in Swaziland's potential irrigation development or an increase in flows entering Swaziland from the RSA.

NGWAVUMA BASIN

The Ngwavuma river arises in Swaziland and discharges into the RSA where it joins the Pongola river. The RSA has not claimed any of the waters of the Ngwavuma river. No downstream border requirements have been assumed in this study. The Pongolaport reservoir created by Strydom dam, which was constructed by the RSA, inundates a portion of

extreme southeastern Swaziland. The value of this servitude has been established at approximately E3 million. The method of compensation for this servitude has not been established.

The references used in this section are 28, 46, 55, 56, 57, 72, and 82, as listed in Section T.

SECTION N

HYDROLOGY

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SECTION N
HYDROLOGY

This section presents the technical analysis and assumptions used to develop an estimate of the surface water availability in the rivers flowing in and through Swaziland. All data and analyses are based on the October through September water year.

PREVIOUS HYDROLOGIC STUDIES

Hydrologic information was obtained from the data provided in the 1970 United Nations Development Program (UNDP) Report which was prepared by Engineering and Power Development Consultants for the Government of Swaziland (GOS).

A regional study of rainfall-runoff relationships and open-water evaporation in and around the Republic of South Africa (RSA), prepared by Professor D. C. Midgley, was used when reliable gaging data were not available.

PRECIPITATION DATA

The GOS has collected precipitation data from 35 precipitation stations in Swaziland. Table N-1 lists the station name, the first

Table N-1
Swaziland Precipitation

Index No.	Station Name	Year Acti-vated	Record Length (years)	Average Annual Amount (meters)	Max. Annual Amount (meters)	Water Year	Min. Annual Amount (meters)	Water Year
1	Johannes Loop	1943	35	1.0	1.67	1956	0.55	1964
2	Nhlangano	1934	44	0.85	1.22	1961	0.57	1952
3	Dwaleni	1915	62	0.76	1.39	1918	0.45	1964
4	Hluti	1913	63	0.87	1.65	1925	0.38	1962
5	Crooks Plantations	1953	25	0.64	1.09	1975	0.38	1962
6	Lavumisa	1929	41	0.58	0.95	1940	0.32	1931
7	Mankayane	1909	69	0.89	1.73	1918	0.39	1965
8	Matsapha	1968	10	0.91	1.2	1942	0.8	1971
9	Hlatikulu	1905	72	1.13	1.93	1925	0.72	1935
10	Kubuta	1918	60	0.78	1.48	1937	0.36	1931
11	Siphofaneni	1935	37	0.66	1.2	1939	0.4	1952
12	Poponyane	1952	26	0.63	0.84	1975	0.4	1968
13	St. Phillips	1929	48	0.57	0.97	1975	0.28	1964
14	Wisselrode	1922	56	0.56	1.07	1972	0.31	1927
15	Mbabane	1903	75	1.4	2.56	1925	0.9	1964
16	Mbuluzi Demofarm	1949	29	1.16	1.64	1972	0.8	1952
17	McCreedy	1919	59	1.14	1.96	1947	0.68	1964
18	Manzini	1897	73	0.92	1.49	1918	0.53	1927
19	St. Josephs	1917	60	0.8	1.41	1918	0.52	1927
20	Mpisi I	1919	59	0.66	1.29	1925	0.25	1964
21	Dinedor	1921	57	0.71	1.23	1943	0.4	1973
22	Mpisi II	1952	26	0.74	1.08	1976	0.39	1964
23	Homestead	1916	62	0.69	1.35	1918	0.35	1964
24	Mpaka	1969	9	0.83	1.27	1972	0.6	1974
25	Vuvulane	1945	33	0.84	1.52	1972	0.33	1964
26	Nokwane	1956	22	0.71	1.13	1972	0.41	1964
27	Siteki	1899	77	0.85	1.61	1918	0.39	1931
28	Swaziland Plantation	1949	29	1.22	1.77	1972	0.71	1964
29	Piggs Peak	1903	75	1.23	2.04	1925	0.72	1964
30	McCorkindale	1948	30	1.52	1.81	1972	0.93	1964
31	Ngonini	1952	26	0.98	1.58	1955	0.67	1962
32	Mayawane	1956	16	1.06	1.26	1971	0.73	1962
33	Tunzini	1952	26	0.73	1.1	1972	0.38	1964
34	Mananga	1952	26	0.75	1.13	1972	0.35	1964
35	Bordergate	1952	26	0.69	0.93	1972	0.33	1964

year of data collection, and the length of record at each station. An index number was assigned to each station for cross reference between table N-1 and plate 10, which shows the station locations.

Annual rainfall in Swaziland varies considerably with location. Table N-1 indicates that average annual rainfall ranges from a high of 1.52 meters at McCorkindale to a low of 0.56 meters at Wisselrode. In most cases, these variations can be attributed to station elevation because the Highveld stations normally record more rainfall than stations located in the Middleveld or Lowveld regions. The year-to-year variations are also significant. A good example of this is the 1.66-meter difference between the maximum and minimum yearly amounts recorded at the Mbabane station. Seasonal distribution of rainfall in the country is notably consistent; most stations show that 80 percent of the annual precipitation occurs during the months of October through March.

STREAM GAGING DATA

Streamflow gaging data for the basins being studied were acquired from the GOS, the RSA, Mozambique, and the Commonwealth Development Corporation. Table N-2 lists the gaging stations that were used for this study. Their locations are shown on plate 11. Although GOS officials and the 1970 UNDP Report expressed considerable concern about the reliability of the data at various gaging stations, it was assumed that all data carried equal weight regardless of their source. Time did not allow detailed analysis of the rating characteristics at each gage site and the scope of this study did not warrant it. In some cases, the synthesized data developed at certain stations for the 1970

Table N-2
Stream Gaging Data

Basin	Gage	Stream	Drainage Area (sq km)	Years of Record (Beginning Water Year)	Source	Average Annual Runoff from Recorded Data (mcm)	Semi-Natural MAR from Adjusted Data (mcm)	Remarks
Lomati	GS-11	Lomati	586	24 (1956)	GOS	174	174	
	X1M12	Mhtambangaft	133	3 (1968)	RSA	8	8	
	X1M14	Lomati	1,111	3 (1969)	RSA	232	244	Adjusted to full record mean of GS-11 by using ratio of overlapping record means.
Komati	X1M01	Komati	5,444	64 (1910)	RSA		585	
	X1M07	Msolip	299	11 (1959)	RSA	67	67	
	SIS WEIR	Komati	7,371	17 (1961)	CDC	785	839	
	X1M03	Komati	8,614	46 (1925)	RSA	1,018	1,058	
Mbuluzi	GS-4	Black Mbuluzi	177	19 (1961)	GOS	71	71	
	GS-3	Black Mbuluzi	710	20 (1960)	GOS	224	224	
	GS-10	White Mbuluzi	224	10 (1965)	GOS	22	22	
	GS-20	Mbuluzi	2,258	6 (1974)	GOS	N/A	N/A	
	Goba	Mbuluzi	3,100	23 (1952)	Mozambique	336	352	Combined with GS-20, Years 1975 thru 1978.
Little Usutu	GS-15	Little Usutu	603	12 (1968)	GOS	160	160	
	GS-2	Little Usutu	1,217	19 (1960)	GOS	416	416	Total record increased to 25 years by using 1954-59 synthesized data in EPDC 1970 Report.
Upper Great Usutu	W5M11	Mpuluzi	909	15 (1957)	RSA	54	54	Area indicated includes an estimated 197 sq km of noncontributing area.
	W5M07	Great Usutu	538	16 (1952)	RSA	61	61	Westoe inflows used for years 1971, 1978 to increase the total record to 24 years.
	W5M08	Bonnie Brook	120	23 (1952)	RSA	13	13	
	GS-1	Great Usutu	2,839	10 (1954)	GOS	N/A	N/A	Areas indicated for GS-1 and GS-9 include an estimated 107 sq km of noncontributing area.
	GS-9	Great Usutu	2,973	16 (1964)	GOS	410	429	GS-9 extended to 1954 using GS-1 factored data in EPDC 1970 Report

Table N-2 (Cont'd)
Stream Gaging Data

Basin	Gage	Stream	Drainage Area (sq km)	Years of Record (Beginning Water Year)	Source	Average Annual Runoff from Recorded Data (mcm)	Semi-Natural MAR from Adjusted Data (mcm)	Remarks
Ngwempisi	W5M03	Miambo	205	13 (1951)	RSA	46	46	Jericho inflows used for years 1970-1978 to increase the total record to 22 years.
	W5M04	Ngwempisi	463	23 (1951)	RSA	44	44	
	GS-21	Ngwempisi	1,526	4 (1975)	GOS	167	201	Adjusted to full record mean of W5M04 by using ratio of overlapping record means.
	W5M05	Hlelo	751	20 (1951)	RSA	86	86	
	GS-22	Hlelo	816	4 (1975)	GOS	101	101	
	GS-5	Ngwempisi	3,165	16 (1963)	GOS	335	360	Total record increased to 25 years by using 1954-1962 synthesized data in EPDC 1970 Report.
Mkondo	W5M06	Mkondo	177	17 (1951)	RSA	33	33	
	W5M10	Mkondo	2,209	8 (1957)	RSA	349	392	Adjusted to full record mean of GS-7 by using ratio of overlapping record means.
	GS-7	Mkondo	3,629	26 (1954)	GOS	461	455	
Lower Great Usutu	GS-6	Great Usutu	12,903	19 (1960)	GOS	1,714	1,803	Total record increased to 25 years by using 1954-1959 synthesized data in EPDC 1970 Report.
	GS-12	Mhlatuzane	367	11 (1966)	GOS	43	43	
	GS-19	Mhlatuzane	528	6 (1972)	GOS	51	51	Adjusted to full record mean of GS-12 by using ratio of overlapping record means.
	GS-13	Mhlatuze	216	12 (1968)	GOS	28	28	
Ngwavuma	GS-8	Ngwavuma	1,305	19 (1961)	GOS	100	95	

UNDP Report were included to increase the record length. In other cases, adjustments were made directly by proportioning from one record period to the next. The remarks column provided in table N-2 identifies the stations that were adjusted.

DEVELOPMENT OF SEMINATURAL MAR

Natural accruals are determined from gaging records that have been adjusted for the effects of manmade changes in water development in a basin. Afforestation is also a manmade change; however, in this part of South Africa, its history dates back to the early 1900's. It can be assumed, therefore, that its effects are reflected in the gaging records. Therefore, the term seminatural mean annual runoff (MAR) was chosen in this study to represent the quantification of annual accruals. The flow record adjustments which were required to develop the seminatural MAR throughout each basin are discussed in the following paragraphs.

LOMATI

Average annual consumptive irrigation use since 1955 was estimated at 12 million cubic meters (mcm) based on 732 irrigated hectares (ha) upstream from gage X1M14. The average annual runoff computed at gage X1M14 was increased by 12 mcm to compensate for these effects.

KOMATI

Recorded flows for all Komati gaging stations (GS) were adjusted upward for volumes withheld by the RSA dams, Nooitgedacht and Vygeboom, for the periods from 1966 to 1978 and from 1972 to 1978, respectively.

The adjustments included recorded reservoir holdouts for powerplant cooling and 60 percent of any water which was released for irrigation. Flows at gage X1M03 were also adjusted for Swaziland Irrigation Scheme (SIS) abstractions. These abstractions were taken from records for 1961 and 1963 to 1970 and were estimated to be 80 mcm annually between 1955 and 1960.

MBULUZI

The flow record at Goba was adjusted by subtracting the estimated return flows from the SIS (0.4 x SIS abstractions) for 1955 to 1974. No adjustments were made to the GS-20 flows that were combined with the Goba record because Goba meters an 845-square-kilometer (sq km) larger area and because of the shorter reach exposure to SIS return flows. Also, the record for the one year in which both gages were measured indicated that the GS-20 and the adjusted Goba values were comparable. A final adjustment of 71 mcm was made to the average annual runoff at the Goba site to reflect water consumptively used by an average 13,900 acres (5,625 ha) of irrigation in the Mbuluzi basin during the period from 1961 to 1978. A record of the number of acres irrigated each year was obtained from the GOS. An annual consumptive use rate of 80 percent was applied to the application rate of 6.9 feet.

LITTLE USUTU

No adjustments were made in the Little Usutu basin.

UPPER GREAT USUTU

The gaging record for the Upper Great Usutu river at GS-9 was adjusted for the effects of Westoe reservoir after 1971. This adjustment included the actual record of reservoir abstractions and 60 percent of the water released for irrigation.

NGWEMPISI

Ngwempisi gaging records at GS-21 and GS-5 were adjusted for the effects of the Jericho and Morgenstond reservoirs after 1970 and after 1978, respectively. These adjustments were based on the actual records of reservoir abstractions and 60 percent of the water released for irrigation.

MKONDO AND NGWAVUMA

As previously discussed, the seminatural MAR includes the effects of afforestation. In most instances, it was assumed that in recent history the change in afforestation acreages was so slight that its effects were considered insignificant. A comparison of Swaziland mapping dating back to 1962 with a 1975 composite satellite photograph indicates the afforestation increases in the Mkondo and Ngwavuma basins have been significant. The afforested area was roughly estimated to have increased by 52 sq km in each basin during this period. The effects of these afforestation changes on the runoff at GS-7 in the Mkondo basin and at GS-8 in the Ngwavuma basin were estimated from information given in the 1970 UNDP Report. Based on that information, mature trees were estimated to reduce annual runoff by 33 centimeters (cm) per year. Assuming that only one-half of the trees are currently mature, afforestation would reduce runoff by only 16.5 cm per year. This translates into a current average annual reduction at each gage of 8.5 mcm; this was subtracted from the gaging station results to get the seminatural MAR estimate. To compensate for the effects of increased afforestation on the flow records back to 1962, the flows at each gage were progressively increased 0.5 mcm annually in 1963, 1.0 mcm in 1964, 1.5 mcm in 1965, and so forth. No estimate of future afforestation effects is included in this analysis.

LOWER GREAT USUTU

The adjustments to flows at GS-6 in the Lower Great Usutu basin were derived by combining the adjustments to GS-9 in the Upper Great Usutu basin and to GS-5 in the Ngwempisi basin, as well as to the afforestation effects in the Mkondo basin.

SEMINATURAL MAR INTERPOLATIONS

Supply-demand analyses and preliminary plan formulation required monthly flow data at many locations within each basin. These data were only available at the gage locations. When flow data at the gage were used at an upstream or downstream location, all flows in the record were multiplied by the ratio of the MAR at the new location to the MAR at the gage. In order to determine the MAR at locations other than the gaging stations, a parameter which could be related to basin runoff was required. Since time did not allow even a preliminary investigation of regional predictors, the drainage area multiplied by the average annual rainfall was selected as the base parameter. Drainage area sizes were either measured from a map or taken from the gaging station data file. Average annual rainfall values were determined for Swaziland by using the precipitation station data shown on plate 10, using Theisen Polygons. For the RSA, average annual rainfall values were determined by using the average annual isohyetal data presented in the 1970 UNDP Report. The resulting curves of MAR are shown on plate 12. All of the basin runoff curves, except the one for the Lower Great Usutu basin, were based on drawing an eye-fit line through the seminatural MAR computed from the gaging data. For the Lower Great Usutu river, the curve downstream from GS-6 was based on the regional rainfall-runoff relationships developed by Professor D. C. Midgley for South Africa.

Rainfall records were of various lengths and generally covered a longer period than the stream gaging records. All relationships were developed using the total record available.

RESERVOIR ANALYSIS

The yield obtainable from the river cannot be determined from a study of annual runoff values. The effects of reservoir storage and abstractions must take into account not only variations in annual flows but also seasonal flows and variations in demand throughout the year. The division of annual flows into monthly volumes is satisfactory for water supply studies of this scope. Because seasonal variations are different in each river basin as well as at locations within each basin, the analysis must be based on recorded data. In this analysis, an operation study was performed on each potential reservoir using the recorded volumes for each month of record to account for both annual and seasonal variations in flow. The large quantity of data handling required automatic data processing. A computer program was used to compare available monthly reservoir inflows, water in storage, and precipitation to monthly water demands. Monthly water demands included downstream requirements minus intervening inflow as well as abstractions directly from the reservoir. Evaporation was subtracted from the reservoir storage each month. If the total demands exceed the monthly inflow and storage supply, the shortage is calculated. A shortage index is derived using all the shortages experienced during the period of record, prorated to 100 years.

INFLOWS

The seminatural MAR curves for the respective basins shown on plate 12 were used to estimate the runoff for the various reservoir sites. If the site was located on the main river channel, a square-mile-inches interpolation was used. If the site was on a tributary, the slope of the MAR curve at the tributary interpolation point was used. In each case, an actual gaging record in the respective basin was used to provide the monthly and yearly flow distributions. The monthly maximums, minimums, and means for the period of record at each station are shown on plate 13. Table N-3 shows the gaging stations used in each basin.

PRECIPITATION

Average monthly precipitation values were used in the model. Stations were selected for their proximity to the reservoir site being studied.

Table N-3
Gaging Stations Used for Reservoir Analysis

Basin	Station Designation
Lomati	GS-11
Komati	X1M01
Mbuluzi	GS-3
Little Usutu	GS-2
Upper Great Usutu	GS-9
Mpuluzi	GS-9
Ngwempisi	GS-5
Mkondo	GS-7
Lower Great Usutu	GS-6
Ngwavuma	GS-8

EVAPORATION

Average annual lake evaporation values were estimated for the potential reservoirs from the regional Symons pan evaporation criteria developed by Professor D. C. Midgley for South Africa. Reduction of these data to an average annual monthly distribution was based on the Swaziland evaporation studies presented in the 1970 UNDP Report.

SEDIMENT

Sediment reserve storage requirements for the potential reservoirs were based on a sediment load study on the Mhlatuzane river at GS-12. The results of this study, as presented in the 1970 UNDP Report, indicated that the total annual sediment load is approximately 0.029 percent of the MAR. A 100-year sediment accumulation using a 90-percent trap efficiency was the design selected for this study.

SEEPAGE

The effects of seepage losses from the reservoir were assumed to be insignificant and, therefore, were not included in any of the analyses made for this study.

RESERVOIR YIELD

A yield-capacity curve was developed for each reservoir site. Several operation studies were required to develop each of these curves. For a given reservoir capacity, the flow record was routed through the reservoir for each of a number of yield levels until the reliable yield

was found. Reliable yield is defined as the yield that could be obtained with a shortage index of 0.25. This was repeated for the number of reservoir capacities sufficient to develop a yield-capacity curve for the reservoir.

SHORTAGE INDEX

The shortage index measures the severity as well as the recurrence of shortages. Large shortages are far more serious in their economic effect than are small shortages, and the economic impact of a shortage is assumed to vary with some power (greater than one) of the percent shortage. The shortage index used in this analysis is a function of the square of the quotient of the shortage divided by the demand. This implies that shortages of 40 percent are four times as serious as shortages of 20 percent and that shortages of 60 percent are nine times as severe as shortages of 20 percent. Use of this relationship permits the development of a single index convenient for planning purposes.

The tolerable shortage adopted for this analysis is represented by a shortage index of 0.25. It is defined as the sum of the squares of all shortages expected during a 100-year period when each annual shortage is expressed as a fraction of the annual demand. This would permit, for example, 25 shortages of 10 percent each during 100 years, about six shortages of 20 percent each, or one shortage of 50 percent, if no other shortages occurred. A shortage index of 0.25 could also result from 12 shortages of 5 percent, five shortages of 10 percent, two shortages of 20 percent, and one shortage of 30 percent in 100 years ($12 \times (0.05)^2 + 5 \times (0.1)^2 + 2 \times (0.2)^2 + (0.3)^2 = 0.25$).

Another value for the power other than the square could be more appropriate. Detailed studies of the economic consequences of shortages in Swaziland for different cropping practices and patterns could result in the use of a different power. Also, an index other than 0.25 may prove to be a better determinant of reliability. The values used in this analysis were developed by the U.S. Army Corps of Engineers in 1963 and have been used in a number of instances in the United States since that time. Shortage records at the SIS weir and the Big Bend weir for a shortage index of 0.25 are shown in Part II, Supply-Demand Analysis; this indicates what a shortage index of 0.25 would mean in actual shortages over the period of record when reservoir storage is not involved. A shortage index of 0.25 tends to result in fairly frequent but not very severe shortages when the demand is provided from run-of-river flows. When storage is involved, the shortages tend to be less frequent but larger in magnitude. In actual reservoir operation, moderate shortages may be taken when the reservoir storage is low in the hope of averting severe shortages later.

COMPARISON WITH RSA-SIMULATED FLOW RECORDS

The RSA has developed simulated MAR values for the Lomati, Komati, Little Usutu, Upper Great Usutu, Ngwempisi, and Mkondo rivers. These data were summarized in a recently published RSA report entitled "Possible Future Development of Rivers of Common Interest with Swaziland," dated January 1980. The monthly border flow data provided in the RSA report were based on existing gaging records extended to water year 1922 by simulation with rainfall records. These simulations were based on a method developed by Dr. W. V. Pitman at the University of Witwatersrand. A comparison of the MAR values presented in the RSA report with the MAR

values developed for this framework report indicates that in most cases the MAR estimates presented in the framework report are higher. MAR values in this report average about 44 percent higher, with the exception of the Komati river where the RSA results were actually higher by 14 to 15 percent. In reviewing the possible explanations for the significant differences between the RSA results and those shown in the framework report, the following four factors were considered:

- record length;
- flow adjustments to reflect natural conditions;
- correlation of simulated flows and gaged flows; and
- transposition or interpolation of data from gage site to border.

RECORD LENGTH

A check of the RSA-simulated flows at the border for the years coincident with the gaging records showed only minor variations from the MAR's determined by the RSA from the full-term analysis. The overall variation averaged only about 9 percent, including negative values as positive variations. It would appear, therefore, that the longer record length generated by the RSA is not responsible for the MAR differences.

FLOW ADJUSTMENTS TO REFLECT NATURAL CONDITIONS

The only information provided in the RSA report concerning adjustments to natural runoff was in connection with afforestation. The effects of afforestation in each catchment as it existed in 1972 was considered natural. This is basically the same concept used in the framework plan except the applicable period of record was extended to

1978. Since the RSA provided a record of the actual amounts of water diverted from each reservoir for irrigation, it is not likely that the adjustments required to convert the recorded flows to natural flows would have caused the MAR differences.

CORRELATION OF SIMULATED FLOWS AND GAGED FLOWS

A correlation was made between the yearly simulated flows generated by the RSA and those available from gaging records in the respective catchments. The correlation coefficients from these studies varied considerably. The best correlation was on the Komati river with a coefficient of 0.9 and the worst correlation was on the Mpuluzi river with a coefficient of 0.2. On a monthly flow basis, these correlation figures become even worse. An analysis of the months of January and July on the Komati river resulted in correlation coefficients of 0.76 and 0.64, respectively, while the same analysis on the Mpuluzi river resulted in correlation coefficients of 0.06 and 0.02. Correlation coefficients of less than 0.8 essentially mean that there is no statistically significant correlation.

To illustrate the effects of these low correlation coefficients on supply-demand analysis, damsite (DS) 4.10 on the Mpuluzi river at the border was examined using both the actual streamflow records and the RSA-simulated flows. The annual yield (shortage index of 0.25) that could be obtained at DS 4.10 without storage and using the actual streamflow records would be 46 mcm. This yield would be only 7 mcm using the RSA-simulated flows over a 54-year record period. Using that portion of the RSA-simulated flows that roughly corresponds to the actual streamflow record period, the annual yield would be 11 mcm.

With a storage capacity of 141 mcm at DS 4.10, the annual yield would be 77 mcm using actual streamflow records, compared to 45 mcm

using the total 54-year RSA-simulated flows, and 82 mcm using the RSA-simulated flows corresponding to the actual record. Analysis under with storage conditions tends to even out the differences between actual and simulated flows.

Using simulated flows that have a poor correlation with actual flows, therefore, can have significant impacts on streamflow yield analysis. While these simulated flows must be developed during detailed planning of the irrigation projects presented in this report, care must be taken to develop simulated flows with high correlations to the actual flow records.

The 1970 UNDP Report also presented the results of a correlation study between annual rainfall and runoff and records at GS-2. The results of this study were statistically significant. Although these results look promising, a considerable study effort would still be required to develop monthly flows. There is also no assurance that the relationships between rainfall and flow records at other GOS gaging stations would be statistically significant.

TRANSPOSITION OR INTERPOLATION OF DATA FROM GAGE SITE TO BORDER

No discussion was provided in the RSA report to describe what catchment parameters were used in the simulation model to extend the recorded monthly flows from the gage sites to the border. Simulation of data based on correlations with coefficients less than 0.8 combined with the inherent errors associated with the adjustments required to transpose the data from one site to another can also produce significant variations in the results. The greater error associated with the monthly flow predictions, as evidenced by the monthly correlations discussed above, would have an even greater impact on the reliability of seasonal water availability estimates.

RECORD LENGTH

In analyzing long records, it has been found that vastly different results can be obtained if different portions of the same record are used. Except for the Komati river (gage X1M01), where the record length is 70 years, the record length is only 19 to 26 years in Swaziland. The values obtained for reliable demand could be different if longer records were available.

As an illustration of the implications of these short records on streamflow yield analysis, the Komati river was analyzed using only that part of the record from 1954 to 1979. This represented 25 years of record which is similar to those records available on the other streams. A total of 144 mcm would be available at the SIS weir using the short record compared to 74 mcm per year using the long record. If only the short period were available, therefore, the water available at the SIS weir would have been overstated by 70 mcm, or about 95 percent.

This analysis was also conducted at DS 6.5 on the Komati river. The analysis shows that with storage, this potential overstatement of water availability is greatly reduced. Three different storage sizes were examined. In all cases, the potential overstatement was less than 10 percent. The yield analysis with storage is, therefore, much less sensitive to record length. This factor is important in plan formulation for irrigation in Swaziland.

This significant difference in the reliability of flows without storage is caused by a disproportionate number of very low and very high flows recorded in the earlier years at gage X1M01. A comparison of the standard deviation of the logarithms of the annual flows for the

two different record periods at gage X1M01 produced a standard deviation of 0.236 for the entire period and 0.160 for the last 26 years. The latter figure is comparable to the standard deviations computed from the other GOS gaging records for approximately the same period of record. This does not mean that the other gaging records can be expanded based on the flow record of gage X1M01. A study presented in the 1970 UNDP Report of correlations between the records of annual flows at gage X1M01 and the GOS gaging stations resulted in correlation coefficients that were too low to be statistically significant.

EMBANKMENT AND SPILLWAY DESIGN

The scope of the studies made for the Supply-Demand Analysis and the preliminary plan formulation did not require detailed cost analysis of the alternative dams considered in the various plans. Generalized cost curves from the 1970 UNDP Report were updated and used in this study. In the 1970 UNDP Report, the height was assumed to be 9 meters above the maximum water storage level. Emergency spillway costs were accounted for in the generalized cost curves.

Detailed cost estimates of each dam would require development of design hydrology for the upstream watershed at each damsite. The safe hydrologic design of a dam requires a spillway discharge capability in combination with an embankment crest height that can handle a very large and exceedingly rare flood without overtopping. Development of a flood of this magnitude requires a detailed analysis of historical runoff events and estimates of probable maximum rainfall conditions for the area being considered. In addition, detailed reservoir routings are

required to develop the optimum relationship between spillway size and embankment size. In some cases, providing more storage between maximum pool and spillway crest can provide the least costly combination.

The references used in this section are 2, 6, 27.5, 84, 85, 86, and 87, as listed in Section T.

SECTION O

HYDROPOWER BENEFITS

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SECTION O
HYDROPOWER BENEFITS

ELECTRICAL ENERGY STATUS AND PROJECTIONS

Swaziland has experienced a rapid recent growth in the use of electrical energy. As measured by total sales to its customers, the Swaziland Electricity Board (SEB) experienced an increase of 76.4 percent from 1975 to 1979. Total sales were 126.3 gigawatt-hours (GWh) in 1975 and 222.8 GWh in 1979. In the same period, peak demand went from 28.5 megawatts (MW) to 53.1 MW, an increase of 86.3 percent. Energy sales to SEB customers are projected to have grown to 256 GWh by 1980 and are projected to be 430 GWh by 1985 and 526 GWh by 1990. For the same time period, peak demand is projected to grow from 59 MW in 1980 to 91 MW in 1985 and 112 MW in 1990.

The current installed generating capacity is 29.5 MW; thus a considerable amount of power must be purchased from an outside source. This source is the South African Electrical Supply Commission (ESCOM), a Republic of South Africa (RSA) concern.

Table O-1 shows pertinent data for the electric utility situation in Swaziland.

The 1980 Merz and McLellan study provided a detailed monthly analysis of projected future electricity demands and of the existing and planned supplies. The analysis showed shortfalls in the SEB's ability to meet demand--given the existing generating capacity and transmission capacity from RSA--as early as March 1981. To help meet this deficit, the SEB is currently undertaking further development of hydroelectric potential at the Luphohlo-Ezulwini Hydroelectric Scheme.

Table O-1
Power Sales
(GWh)

Demand	Actual 1975	Actual 1979	Projected 1980	Projected 1985	Projected 1990
Total GWh Sales	126.3	222.8	256.0	430.0	526.0
Domestic Consumers	(21.6)	(41.0)	(49.0)	(89.0)	(125.0)
Commercial and Industrial	(13.8)	(22.0)	(25.0)	(40.0)	(53.0)
Irrigation Consumers	(24.4)	(61.6)	(77.0)	(144.0)	(155.0)
Power and Bulk Supply	(66.5)	(98.2)	(105.0)	(157.0)	(193.0)
System Losses	14.0	25.0	28.0	48.0	58.0
Total Sent Out	140.3	247.8	284.0	478.0	584.0
Imported from ESCOM	18.0	104.0	-	-	-
Percent of total sent out by the SEB 1/	13	42	-	-	-
Peak Demand, MW (percent)	28.5	53.1	59.0	91.0	112.0
System Annual Load Factor (percent)	56.1	53.3	55.0	60.0	60.0

1/ The 1976 through 1978 percents of total sent out were: 1976, 24; 1977, 28; and 1978, 46.

Source: Merz and McLellan, 1980

Even with this development, however, the SEB has determined that more power and energy are necessary. Two new feeder lines from ESCOM are currently being considered to help provide additional electric power for Swaziland's near-term needs.

An additional hydroelectric scheme, termed the lower station, and various combinations of hydroelectric schemes and additional purchases from ESCOM were also considered. The SEB's consultant analyzed the feasibility of installing coal-fired generating capability but found that this alternative was not economically attractive compared to additional hydroelectric capacity or additional purchase from ESCOM.

In any case, the SEB has determined that additional electrical power is needed and that this additional power will either be hydroelectric or additional purchases from ESCOM. The firm power from ESCOM feeders 1 and 2 (67 MW nonfirm, 36 MW firm) and the SEB generating capacity (20.5 MW hydroelectric, 9.0 MW diesel turbine) currently provide a total capacity of 65.5 MW. This is sufficient to meet the current peak demand of 59.0 MW. By 1985, however, peak demand will be about 91.0 MW. The Luphohlo-Ezulwini Hydroelectric Scheme will add 20 MW of capacity. Even with this scheme, more capacity will be needed.

BENEFIT DEFINITION AND ESTIMATES

For purposes of analyzing the benefits and feasibility of including hydropower as part of a multipurpose project, power purchases from ESCOM are considered as the most likely alternative. Thus, the value of hydropower benefits is equal to the costs that would otherwise accrue in purchasing power from ESCOM. These costs consist of the capacity

charges (also termed demand charges or monthly extension charges) paid to ESCOM, the energy charges per kilowatt-hour (KWh) actually used, and the construction costs that the SEB would incur to transport the power into Swaziland.

These capacity charges, energy charges, and construction costs are estimated below.

• Monthly capacity charge: E4.03 per kilowatt (E4030 per MW) of maximum power charge per month, or E48,360 per year.

• Energy unit charge: E0.0083 per KWh of energy supplied by ESCOM.

• Construction costs for ESCOM 3 and ESCOM 4 overhead feeder lines and for transformer reinforcements and additional substations: E2423 per MW per year. These construction costs are itemized on page 0-5 using data and September 1979 prices from Merz and McLellan, 1980.

This construction cost of E8,725,000 would accrue from adding 72 MW of capacity, an average of E121,180.56 per MW. Assuming a project life of 50 years, this represents an annual cost of E2,423 per MW.

Capital Costs for ESCOM Feeder Line 3 with 36 MW capacity (nonfirm)	Labor	E 872,000
	Material	E 49,000
	Payment to RSA	E1,572,000
	Currency Expendi- ture	E 195,000
Feeder Line 3 Total		E2,688,000

Capital Costs for ESCOM Feeder Line 4 (same capacity and costs as Feeder Line 3)	E2,688,000
Transformer reinforcements and additional substations	E3,349,000
Total Construction Costs	E8,725,000

For purposes of assessing the economic implications of any hydroelectric proposals associated with proposed irrigation schemes, hydropower benefits can be estimated using the previously described alternative cost estimates.

Annual power benefits:	E48,360 per MW (ESCOM capacity charges)
	2,423 per MW (construction costs)
	E50,783 per MW

Annual energy benefits: E0.0083 per KWh.

The reference used in this section is 4, as listed in Section T.

SECTION P

IRRIGATION BENEFIT ANALYSIS

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SECTION P

IRRIGATION BENEFIT ANALYSIS

Irrigation benefits are equal to the difference between the net revenues with irrigation and the net revenues without irrigation.

NET REVENUES WITH IRRIGATION

Net revenues are a function of crop prices, crop yields, crop mix, and variable production costs. The crop mix used in this analysis is presented in detail in the Water Use and Consumption Section.

Table P-1 presents the crop prices used in this analysis.

Crop yield data are presented in table P-2. Several sources were consulted to obtain these data. These sources include the 1970 United Nations Development Program (UNDP) Report, the 1972 Mbuluzi Report, and the Crop Profitability Guide Book No. 6. The yield data from all three reports were very similar except for cotton; the yield data for cotton were considerably lower in the 1970 UNDP Report than in the other two reports. The higher value was used in this study.

Gross revenues per hectare for the various crops are simply the crop yield multiplied by the crop price. Information from several sources indicated that in the case of sugarcane, one crop in five is a planted or mother crop and the next four crops in five are resprouted ratoon crops. The gross return for sugarcane was weighted accordingly. Expected gross revenues per hectare for the various crops are presented in table P-3.

Table P-1
Crop Prices
(Emalangeni (E) per metric ton)

Crop	Price
Sugarcane (sucrose)	141.60
Cotton	452.90
Maize	120.80
Rice1/	373.00
Vegetables:	
Potatoes	151.20
Tomatoes	111.00
Onions	151.20
Green Beans	151.20
Cabbage	151.20

1/ Information indicated that 10 percent of the rice crop is sold at roadside prices of E554.30 per ton and the remainder is sold at E352.80 per ton.

Sources: Crop Profitability Guide Book No. 6, Monthly Market Information Bulletin, and discussions with Ministry of Agriculture personnel

Table P-2
Crop Yields in Metric Tons Per Hectare

Crop	Yield
Sugarcane (12.5 percent sucrose)	
Mother crop	133 (16.7 tons sucrose)
Ratoon crop	111 (13.9 tons sucrose)
Cotton	3.9
Maize	4.4
Rice	3.6
Vegetables:	
Potatoes	22
Tomatoes	20
Onions	27
Green Beans	9
Cabbage	27

Table P-3
Gross Revenues Per Hectare

Crop	Gross Revenues (E)
Sugarcane	2,049.40
Cotton	1,764.30
Maize	537.70
Rice	1,328.40
Vegetables:	
Potatoes	3,365.50
Tomatoes	2,223.90
Onions	4,037.60
Green Beans	1,346.20
Cabbage	4,037.60

Detailed information on production costs was available from several sources including the 1970 UNDP Report, the 1972 Mbuluzi Report, and the 1980 Lusushwana Report. Crop input costs in the 1972 Mbuluzi Report were updated based upon changes in the prices of major inputs from 1972 to the present time. Updates of prices for seed, fertilizer, insecticides, and machinery are based on information obtained from Crop Profitability Guide Book No. 6. Other input costs were updated based upon various price indexes obtained from the Government of Swaziland (GOS). The actual quantities of inputs assumed to be used by the various crops are the same as those recommended in the 1972 Mbuluzi Report.

Farm machinery costs were converted to variable rates assuming useful operating lives for the various types of machinery employed. Thus, all machinery costs are "charged out" as variable crop production costs.

The updated variable production costs per hectare are presented in table P-4.

Net revenues are the difference between the gross revenues presented in table P-3 and the variable production costs presented in table P-4. Net revenues per hectare for the various crops are presented in table P-5.

Table P-4
Variable Production Costs in Emalangeni Per Hectare

Cost Items	Sugarcane: Mother Crop	Sugarcane: Ratoon Crop	Cotton	Maize	Rice	Potatoes	Tomatoes	Cabbage	Onions	Green Beans
	Crops									
Seed	103.80	-	5.90	28.20	34.60	378.10	19.80	5.90	85.50	47.90
Fertilizer	141.30	85.00	61.80	90.70	158.10	224.90	271.80	142.30	124.50	80.30
Insecticide	18.80	18.80	66.50	27.20	24.70	24.70	-	24.70	-	-
Fire Insurance	4.70	4.70								
Field Machinery 1/	217.40	63.00	135.90	126.00	163.10	397.80	74.10	311.30	268.60	170.70
Transportation and Loading	440.30	410.90	-	-	-	-	-	-	-	-
Labor	-	-	103.30 2/	-	-	-	-	-	-	-
Bags	-	-	-	23.50	23.50	151.50	-	105.80	302.90	126.80
Herbicide	-	-	-	41.80	83.50	-	-	-	-	-
Fungicide	-	-	-	-	-	8.90	247.10	-	-	24.70
Contract Harvesting	-	-	-	-	76.10	-	-	-	-	-
Boxes	-	-	-	-	-	-	667.20	-	-	-
Spraying	-	-	-	-	12.60	-	-	-	-	-
Total	926.30	582.40	373.40	337.40	576.20	1,185.90	1,280.00	590.00	781.50	450.40

1/ In the case of vegetables, the figures in this row refer to a general cost category "Machinery," which can be both Field Machinery and Transportation and Loading.

2/ Casual labor for picking

Table P-5
Net Revenues in Emalangeni Per Hectare

Crop	Gross Revenues	Variable Production Cost	Net Revenues
Sugarcane	2,049.40	652.30	1,397.10
Cotton	1,764.30	373.40	1,390.90
Maize	537.70	337.40	200.30
Rice	1,328.40	576.20	752.20
Potatoes	3,365.50	1,185.90	2,179.60
Tomatoes	2,223.90	1,280.00	943.90
Onions	4,037.60	781.50	3,256.10
Green Beans	1,346.20	450.40	895.80
Cabbage	4,037.60	590.00	3,447.60

Plan formulation was conducted using one particular crop mix to determine benefits. It was, therefore, necessary to determine the weighted average net revenues per hectare for the crop mix used. These net revenues are shown in table P-6.

Table P-6
Weighted Average Net Revenues in Emalangeni Per Hectare

Crop	Percent of Total Crop	Net Revenues	Weighted Net Revenues
Sugarcane	15	1,397.10	210
Cotton	48	1,390.90	667
Maize	17	200.30	35
Rice	20	752.20	151
Potatoes	11.4	2,179.60	247
Tomatoes	11	943.90	104
Onions	2.4	3,256.10	79
Green Beans	3.9	895.80	35
Cabbage	1.2	3,447.60	42
Total Weighted Average Net Revenues Per Hectare			1,570

NET REVENUES WITHOUT IRRIGATION

Virtually all nonirrigated farming in the Lowveld region is subsistence agriculture. There are some measurable economic returns from subsistence agriculture. Income survey data presented in the 1970 UNDP Report indicate that income from the sales of crops averages E30 per year for Lowveld homesteads engaged in subsistence agriculture. More recent data indicate that the net revenues are less for the great majority of the land. Without irrigation, 7 crops in 10 will not survive in the Lowveld region. Net revenues in the Lowveld region without irrigation are considered insignificant.

An update of information in the 1970 UNDP Report indicates that net revenues from dryland maize production in the Middleveld region are about E173 per hectare. Information from the Swaziland MOA indicated that dryland cotton production in the Middleveld region yields net revenues of around E297 per hectare. Assuming a crop mix of 50-percent maize and 50-percent cotton, net revenues without irrigation in the Middleveld region are estimated to be E235 per hectare. A recent study by the World Bank indicates that even the maximum net revenues possible with optimum management are not significantly higher than this.

NET IRRIGATION BENEFITS

Net irrigation benefits are the difference in net revenues with and without irrigation.

Economic returns in the Lowveld region without irrigation are considered insignificant. Thus, net economic benefits due to irrigation in the Lowveld region are approximately E1,570 per hectare.

Net revenues in the Middleveld region without irrigation are estimated at E235 per hectare. The difference between these two figures, E1,335 per hectare, represents net irrigation benefits in the Middleveld region.

LIMITATIONS OF THE ANALYSIS

The net benefits per hectare derived in this analysis are quite substantial. Optimistic yields were used for all of the irrigated crops. These yields reflect above-average management and good weather conditions. Input costs are based mostly on updates of data from 1972.

The yields for vegetables are especially optimistic because the aspects of spoilage, waste, and loss on the way to market were not considered. Thus, the yields should be considered upper limits. In order to properly account for spoilage and waste, knowledge of the particular marketing arrangement and marketing chain is required.

The prices used in the analysis reflect recent, rather favorable prices for most of the commodities, rather than long-run moving average agricultural prices such as those used in the United States to analyze the economic feasibility of Federal irrigation projects.

This study does not consider the effects of an increase in supply on commodity prices but implicitly assumes that the increased supplies

due to irrigation would have no significant impacts on prices. During detailed studies, price-quantity relationships among the various crops would have to be investigated.

In order to attain the weighted net revenues, a situation such as that at the Vuvulane irrigation project is required. This situation is characterized by the use of farm machinery from a common motor pool, thereby spreading fixed costs and taking advantage of centralized maintenance and repair facilities and skills. Also, an effective agricultural extension service is in operation which disseminates information and helps farmers acquire the skills to obtain higher yields and to minimize costs.

The references used in this section are 1, 2, 13, 26, 35, 36, 72, and 74, as listed in Section T.

SECTION Q

COST ESTIMATES

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COST ESTIMATES

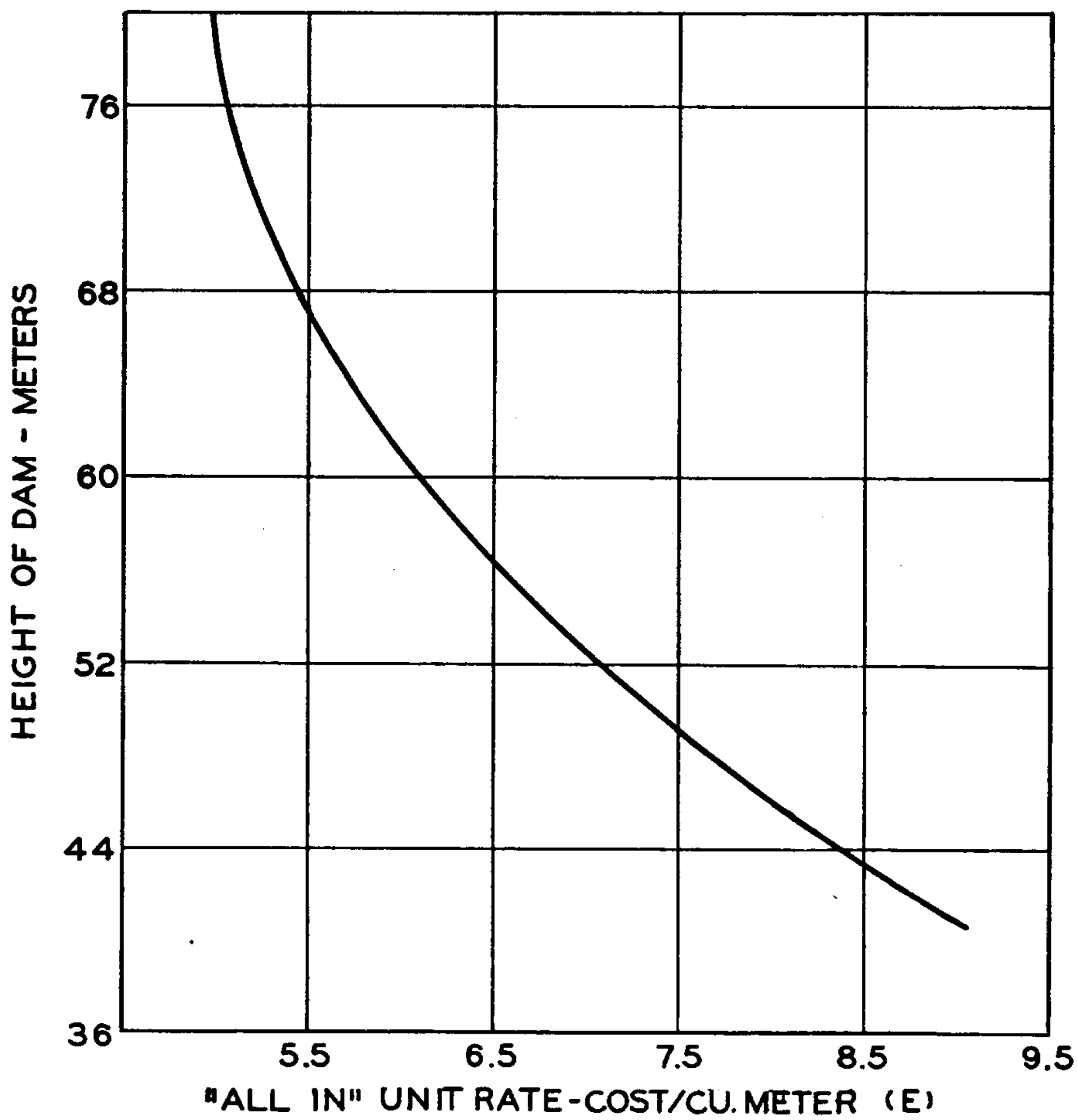
DAMS

The cost estimates for the damsites are based on the cost estimating data and procedures in the 1970 United Nations Development Program (UNDP) Report. Procedures were developed in the 1970 UNDP Report that related the total cost of a dam and ancillary works, including contingencies and engineering costs, to the embankment volume and height. The ancillary works include the spillway and diversion structures. The end result was a curve that related costs per unit volume to height. Detailed cost estimates for damsite (DS) 0.1 were used to develop the relationship. This dam would be an earthfill dam with a side channel spillway and a tunnel diversion. The dam height-unit cost relationship was updated to August 1980 price levels. The update was based on construction cost indexes, bid prices for Mnjoli dam, and estimates contained in the Draft Pre-Investment Report on Hydro-Electric Projects. The updated relationship is shown in figure Q-1.

DIVERSIONS

For some alternatives, a diversion structure is required without a dam. In these situations, the diversion structure costs are based on general cost relationships developed for use in the Ogallala-High Plains study in the United States. These relationships are shown in figure Q-2.

VARIATION OF UNIT COST WITH HEIGHT OF DAM



$$\text{"ALL IN" UNIT RATE} = \frac{\text{TOTAL COST OF DAM \& ANCILLARY WORKS}}{\text{TOTAL VOLUME OF FILL MATERIAL}}$$

FIGURE Q-1

DIVERSION STRUCTURE COSTS

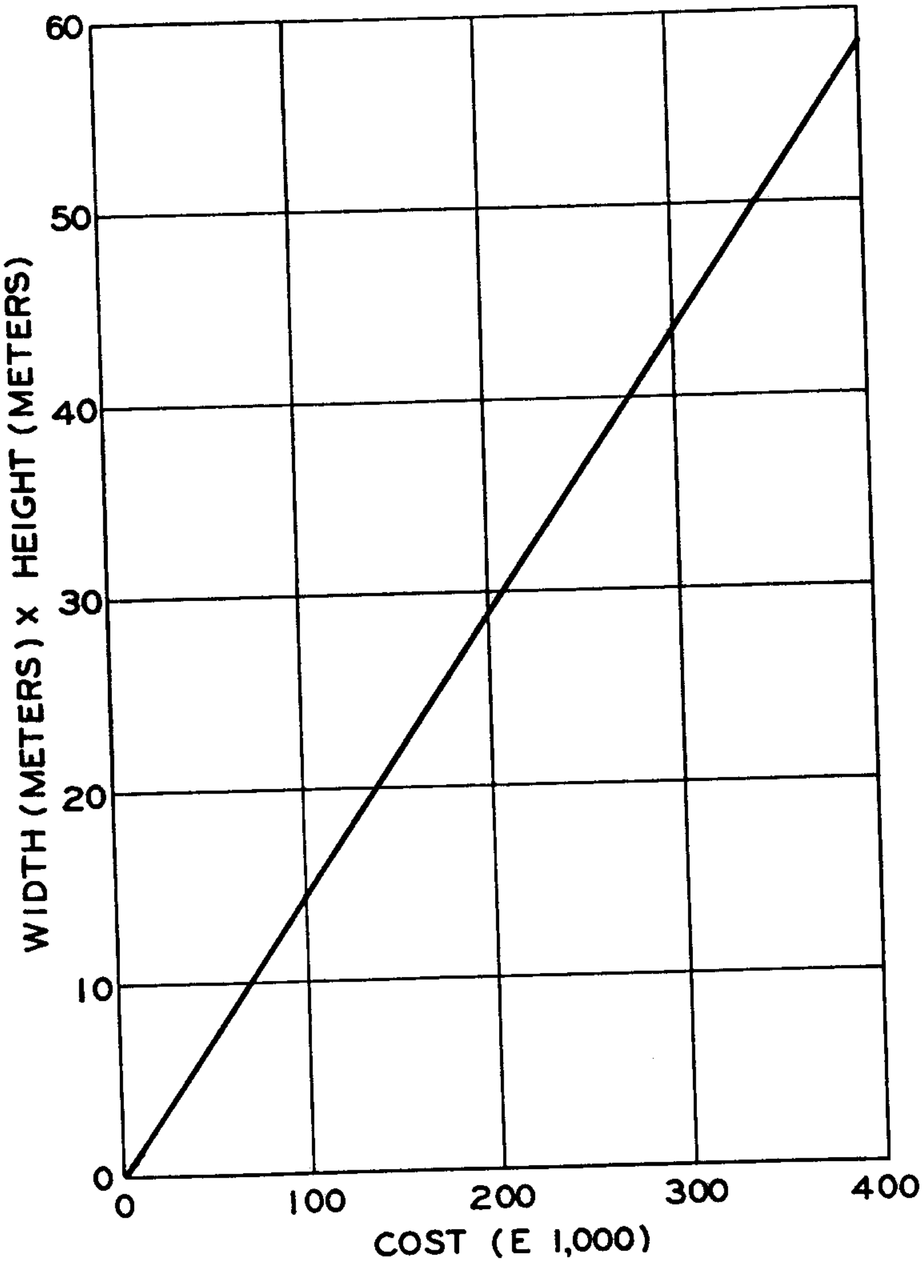


FIGURE Q-2

DELIVERY SYSTEM

The delivery system costs are one of the major costs in any irrigation scheme. The delivery system includes the facilities required to transport irrigation water from the source to the edge of a field. The major components of the delivery system are the main canals, pumping stations, interior mains and siphons, distribution canals, and night storage dams.

The irrigation schemes analyzed in this study use only gravity flow to deliver the water from the source to the general vicinity of the irrigation lands. Some pumping may be required to distribute water within an irrigation scheme.

Cost information for main canals is based on estimates in the 1970 UNDP Report. These estimates related cost per linear yard of canal to discharge in cusecs. This relationship was updated to 1980 price levels, was converted to metric, and is shown in figure Q-3. The update is based on changes in the construction cost index.

Other delivery system costs include those of pumping stations, interior mains and siphons, distribution canals, and night storage dams. The costs of these other delivery system components are related to the number of hectares irrigated. Cost estimates for these delivery system components are based on estimates contained in the Third Sugar Report. These estimates were updated to 1980 price levels using changes in the construction cost index. These updated cost estimates are shown in table Q-1.

LINED CANAL COST
E PER LINEAR METER

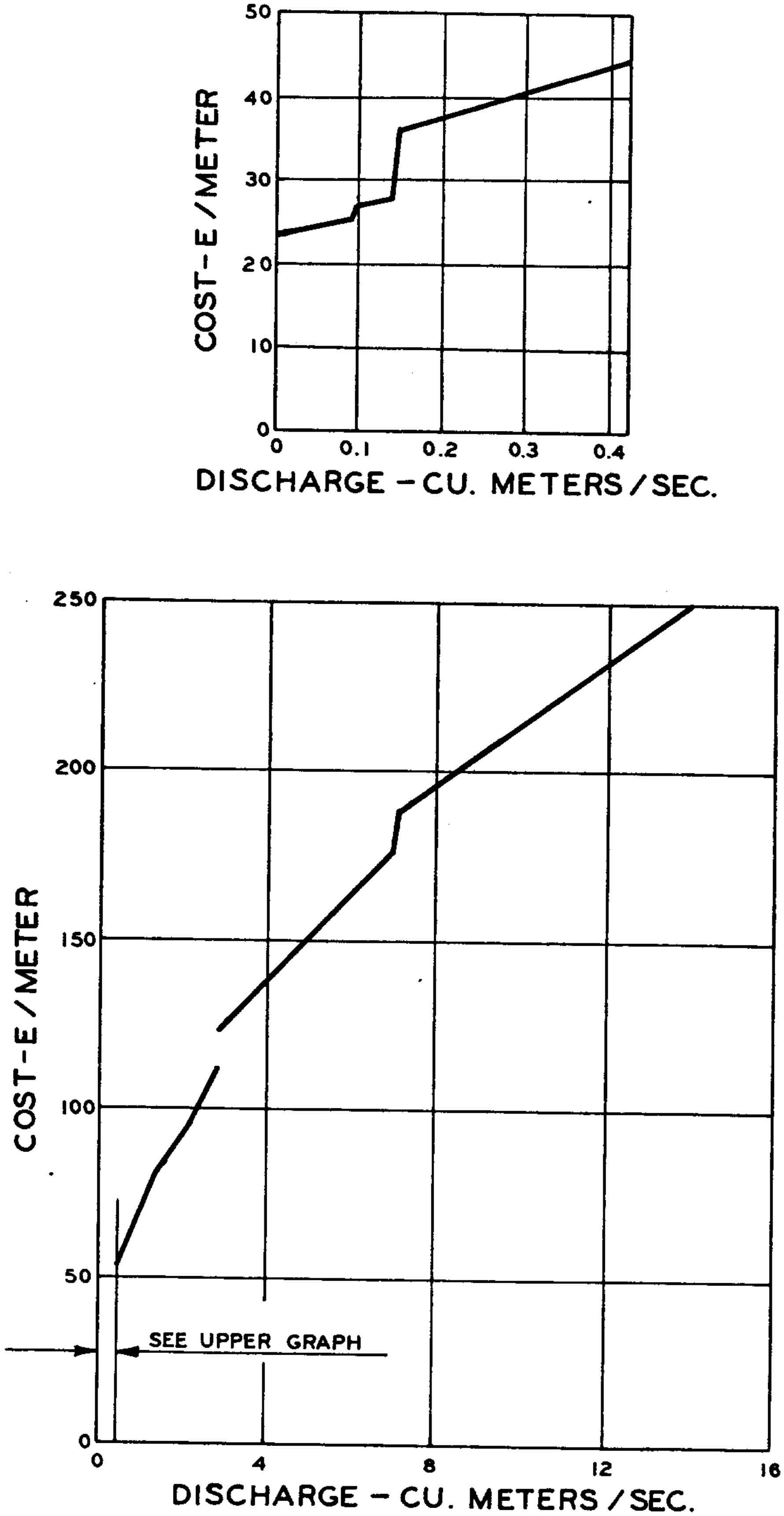


FIGURE Q-3

Table Q-1
Water Delivery Costs[1/]
(per hectare)

Components	Cost
Pumping stations	E355
Interior mains and siphons	136
Distribution canals	200
Night storage dams	27
Total	E718

1/ August 1980 price levels (main canals not included)

DRAINAGE SYSTEM

The drainage cost estimates presented here include costs for interceptor drains, main drains, and, if necessary, lateral tile drains. The interceptor drains are located between farms and collect runoff from farming units. Main drains collect water from the interceptor drains. The costs for interceptor drains and main drains were obtained by updating costs found in the Mbuluzi Report. The resulting cost for main drains is E133 per hectare and the cost for interceptor drains is E77 per hectare. Some soils would require a complete system of lateral tile drains. A United States drain contractor indicated that a complete system with laterals spaced 25 meters apart would cost approximately E1,132 per hectare.

LAND PREPARATION

These costs include such measures as clearing the land of any trees, bushes, or other vegetation and such activities as ripping, discing, land leveling, and contouring.

Land preparation costs are based on an update of a detailed estimate obtained from the Third Sugar Report commissioned by the Government of Swaziland.

This estimate included complete preparation for furrow irrigation in a Lowveld area with heavy brush and very few trees. The updated estimate for land preparation is E588 per hectare.

INTEREST DURING CONSTRUCTION

Interest during construction is an important cost when there is a significant time lag between the time capital is invested and the time benefits begin to accrue. This time lag is estimated to be 5 years. Interest during construction was estimated assuming that the total construction cost would be distributed evenly over the 5-year period and that the interest rate would be 8 percent per year.

OPERATION AND MAINTENANCE

Annual operation and maintenance (O&M) costs for dams were estimated to be one-half of 1 percent of the construction cost.

Annual O&M costs for the irrigation and drainage systems were obtained by updating the detailed estimates in the Third Sugar Report. The updated cost for irrigation and drainage systems is E227 per hectare. It is made up of costs for fuel and power (E173 per hectare), off-farm labor (E2 per hectare), and on-farm labor (E52 per hectare).

CONTINGENCIES

All cost estimates are "order of magnitude" in accuracy as agreed to in the Terms of Reference and should be used accordingly. They are only of sufficient accuracy to determine the relative magnitude of the required investment and to determine if the various alternatives are likely to be economically feasible. These estimates were in most cases derived from estimates made in previous studies. The cost estimates in these previous studies varied widely in detail and accuracy. Each of the estimates included different factors for contingencies and indirect costs. It is impossible to determine with any accuracy the portion of the aggregated construction cost estimate that is for engineering, design, and supervision and construction or what portion represents a contingency for the uncertainties of this scope of planning. Detailed

cost estimates based on detailed plans are required during the next stage of planning.

The references used in this section are 2, 4, 12, 13, and 13.5, as listed in Section T.

SECTION R

WATER USE AND CONSUMPTION

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SECTION R
WATER USE AND CONSUMPTION

IRRIGATION

Data on existing irrigated land were obtained from the Government of Swaziland (GOS). These data were presented by location within each river basin and are summarized in table R-1.

Table R-1
Existing Irrigated Land
(hectares)

Basin	Freehold Title Land	Swazi Nation Land	Total
Lomati	486	246	732
Komati and Mbuluzi	18,569	94	18,663
Little Usutu and Upper Great Usutu	3,146	112	3,258
Ngwempisi	528	63	591
Mkondo	217	34	251
Lower Great Usutu	10,671	161	10,832
Ngwavuma	2,416	191	2,607
Total	36,033	901	36,934

In the lower reaches of the Komati and Mbuluzi basins, there is a large contiguous tract of irrigated land; the specific portion of this tract in each basin was not specified in available data. This tract is composed of the Swaziland Irrigation Scheme (SIS), the Vuvulane irrigation project, and the Tambukulu and Simunye estates and represents about 18,200 hectares (ha) of the total irrigated lands in these two basins. Most of this large tract is located in the Mbuluzi basin; however, about 70 percent of these lands are irrigated by the Komati river

from the SIS diversion weir. The lands which will be irrigated by 1983 in the Ngomane area in the Mbuluzi basin are not included in the figures shown in table R-1.

Irrigation water demands were estimated by first obtaining the water requirements for the various irrigated crops. Several sources were consulted for purposes of obtaining these crop water requirements, including previous reports on potential irrigation projects as well as sources within the GOS.

Crop water requirements are a function of several factors. These factors include average rainfall and the portion of this rainfall that is considered effective rainfall, evapotranspiration, the efficiency of water application for the type or types of irrigation systems employed to apply water to crops in the field, and the "canopy factor." Because these factors can vary between the Highveld, Middleveld, and Lowveld regions, water requirements for irrigation will be different depending upon the location of a particular irrigation area. The gross water requirements were developed, based on these factors, by crop type for each month of the year. Most of the available data used to compute water requirements, however, are for irrigation in the Lowveld region. This information is presented in detail in the following paragraphs.

Table R-2 shows the gross water requirements for the principal irrigated crops grown in the Lowveld region. The gross water requirements shown in table R-2 are derived from net irrigation requirements after adjustment for a 60-percent field application efficiency. In the case of sugarcane, for example, the net irrigation requirement is 1.2 meters. The net irrigation requirement is derived by considering the adjusted monthly evapotranspiration value and subtracting the mean monthly effective rainfall. In the 1972 Mbuluzi Report, effective rainfall is defined as 70 percent of the precipitation mean.

Table R-2
Monthly Irrigation Requirements in the Lowveld Region
(meters)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
Sugarcane	0.20	0.18	0.20	0.15	0.13	0.1	0.13	0.18	0.20	0.20	0.15	0.25	2.07
Cotton	0.20	0.08	0.05	--	--	--	--	--	--	0.05	0.1	0.13	0.61
Maize	--	--	--	--	--	--	--	0.08	0.13	0.20	0.15	0.15	0.71
Rice	0.33	0.3	0.1	--	--	--	--	--	--	0.15	0.23	0.33	1.44
Potatoes	--	--	--	0.05	0.1	0.1	0.13	0.1	0.05	--	--	--	0.53
Tomatoes	--	--	0.03	0.05	0.13	0.1	0.13	0.1	0.05	0.03	--	--	0.62
Cabbage	--	--	--	--	0.03	0.05	0.13	0.18	0.1	--	--	--	0.49
Onions	--	--	0.01	0.01	0.08	0.08	0.13	0.13	0.05	--	--	--	0.49
Green Beans	--	--	--	--	0.05	0.05	0.13	0.1	--	--	--	--	0.33
Wheat	--	--	--	--	0.08	0.1	0.15	0.20	0.08	--	--	--	0.61

Source: Water Resources Development Plan for the Mbuluzi River, Volume I, Technical Annexure II, Appendix IV, February 1972

The adjusted monthly evapotranspiration value is derived by considering the mean of monthly potential evapotranspiration recorded in the Lowveld region and adjusting these measurements to allow for a canopy factor. The canopy factor is an adjustment that accounts for the amount of water required during various stages of growth. The 60-percent application efficiency is for furrow irrigation. The crop water requirements did not vary appreciably among the various cited sources that were reviewed.

Using the figures shown in table R-2, water requirements for the Lowveld area can be estimated based on the percentage breakdown of cropland by type of crop. Estimating such a percentage breakdown of crop mix is, by nature, a problem of gross averaging because crop mix can vary considerably from location to location. For purposes of this study, it was necessary to present an overall average crop mix for the Lowveld region. It was possible, however, to obtain an estimated crop mix by two types of farming--sugar dominated and nonsugar dominated. These two types of crop mix are presented in table R-3.

In order to accurately estimate the amount of water necessary to irrigate a given number of hectares, it is necessary to consider another factor--the efficiency of the water delivery system. This factor should be differentiated from the efficiency of the field application system which was already considered in the above discussion. A delivery efficiency of 80 percent was assumed for this study. This figure was used after consulting several sources and it corresponds to the delivery efficiency recommended in the 1970 United Nations Development Program (UNDP) Report.

The water requirements presented in table R-2 were applied to the crop mixes presented in table R-3 to develop weighted average monthly irrigation requirements for the two types of crop mix. The water delivery efficiency of 80 percent was applied to these monthly requirements

Table R-3
Crop Mix in the Lowveld Region
(percent of total land)

Crop	Sugar Dominated	Nonsugar Dominated
Sugarcane	60	15
Maize	3	17
Cotton	9	48
Rice	21	20
Vegetables:	3	30
Potatoes	--	(11)
Tomatoes	--	(11)
Onions	--	(3)
Green Beans	--	(4)
Cabbage	--	(1)
Wheat	4	0
Total	100	130 1/

1/ The figures for the nonsugar-dominated crop mix add to more than 100 percent because the same land is used for more than one crop in a year. Irrigation water demands were estimated monthly, and this aspect was automatically considered in the calculations.

Sources: 1972 Mbuluzi Report, 1970 UNDP Report

to determine the total amount of water that would be required for irrigation. This is presented in table R-4.

Data on irrigation requirements in the Middleveld and Highveld regions are very limited. The pineapple crop, which is not irrigated, is one of the most widely grown crops in these areas. Limited irrigation requirement data were obtained from the GOS. These were combined with rough estimates of crop mix and the 80-percent delivery efficiency factor to develop the monthly diversion requirements presented in table R-5. The crop mix used in developing this table included citrus, maize, summer and winter vegetables, beans, cotton, rice, wheat, and pasture.

Table R-4
Total Monthly Diversion Requirements for
Irrigation in the Lowveld Region
(meters)

Month	Sugar-Dominated Crop Mix	Nonsugar-Dominated Crop Mix
January	0.26	0.24
February	0.22	0.15
March	0.19	0.10
April	0.12	0.05
May	0.10	0.06
June	0.09	0.05
July	0.11	0.07
August	0.15	0.09
September	0.16	0.08
October	0.21	0.15
November	0.19	0.18
December	0.30	0.26
Total	2.10	1.48

Table R-5
Total Monthly Diversion Requirements for
Irrigation in the Middleveld and Highveld Regions
(meters)

Month	Diversion Requirement
January	0.19
February	0.13
March	0.12
April	0.10
May	0.12
June	0.12
July	0.13
August	0.15
September	0.15
October	0.16
November	0.15
December	0.21
Total	1.73

The figures in table R-6 do not reflect consumptive use. In order to arrive at this figure, it is necessary to estimate the percentage of the water requirements that become return flows.

Because this study is concerned with overall water use and balance, consumptive use was defined as that portion of the flows which do not return to the river source. Consumptive use is primarily attributable to evaporation from dams, canals, and ditches; evapotranspiration from crops; water which becomes part of a crop's moisture content; and seepage into ground water. For purposes of this study, it was assumed that 20 percent of the total water diverted from irrigation would return to the river source in the form of surface runoff. Consumptive use would, therefore, be 80 percent of the total irrigation water requirements shown in table R-6, or about 572 million cubic meters (mcm) total irrigation consumptive use in Swaziland.

The diversion requirements presented in tables R-4 and R-5 were applied to the total existing irrigated land presented in table R-1 to determine the total diversion requirements for irrigation in each basin. These diversion requirements are presented in table R-6.

Table R-6
Total Irrigation Diversion Requirements
(mcm)

Basin	Freehold Title Land	Swazi Nation Land	Total
Lomati	8.4	4.3	12.7
Komati	170.0	1.3	171.3
Mbuluzi 1/	228.1	0.6	228.7
Little Usutu	9.0	1.0	10.0
Upper Great Usutu	54.5	1.9	56.4
Ngwempisi	9.1	1.1	10.2
Mkondo	3.8	0.6	4.4
Lower Great Usutu	210.9	2.2	213.1
Ngwavuma	49.7	3.2	52.9
Total	743.5	16.2	759.7

1/ Requirements by 1983 with full development of Ngomane Irrigation Scheme

MUNICIPAL AND INDUSTRIAL WATER DEMANDS AND USE

In this report, the total water drawn into a community is termed water demand. Some of that water returns to surface flows and is not considered a consumptive use. Consumptive use is the term applied to water not returned to surface flows.

WATER DEMANDS

Water demands were prepared for the 17 urban communities in the country. Municipal and industrial water demand data for six of the largest of these communities were obtained from the Water and Sewerage Board. Those data are summarized in table R-7.

Table R-7
Municipal and Industrial Water Demand Data
(1975-1976)

Community	Average Monthly Use (cubic meters)	Average Per Capita Use (liters/day)
Mbabane	163,705	245
Manzini1/	223,462	280
Nhlangano	21,007	338
Piggs Peak	16,422	240
Hlatikulu	7,864	218
Siteki	10,437	183

1/ Includes Matsapha

Source: Water and Sewerage Board Plans

The Water and Sewerage Board has prepared annual projections of water demands to 1992 for each of these six communities. This source provided the projections for 1985 and 1990 presented in table R-8.

Table R-8
Municipal and Industrial Water Demand Projections

Community	1985 Average Daily per Capita Demand (liters/day)	1985 Average Daily Demand Total (cubic meters)	1990 Average Daily per Capita Demand (liters/day)	1990 Average Daily Demand Total (cubic meters)
Mbabane1/	293	15,350	323	23,550
Manzini2/	334	14,400	369	20,750
Nhlangano	404	47,340	446	67,380
Piggs Peak	284	38,040	314	64,590
Hlatikulu	261	12,660	287	17,760
Siteki	219	36,420	241	43,380

1/ Future service is projected to include Ezulwini Valley and Lobamba

2/ Includes Matsapha

Source: Water and Sewerage Board Plans

CONSUMPTIVE USE

Consumptive use was calculated as the community's total daily demand minus daily treated wastewater returns to surface water. Very little data are available on wastewater treatment facilities for any of these communities. Combined facilities for the Manzini-Matsapha area have a throughput capacity of 4,400 cubic meters per day; this is about 60 percent of the total daily water demand for the area. Therefore, about 40 percent of total daily demand is considered consumed. The Mbabane wastewater treatment facilities have a throughput capacity of 1,800 cubic meters per day, or about 33 percent of the total daily water use. Therefore, about 67 percent of total daily demand is consumed. It is estimated that most of the consumed water is wastewater being accommodated by individual septic tanks. Future wastewater treatment plans call for substantial increases in the throughput capacity of these systems. This increase, however, would merely keep pace with expected increases in water demand. The rate of total consumptive water use as a percent of total demand would, therefore, remain about the same.

WATER USE PROJECTIONS

Low, medium, and high projections of municipal and industrial water use were developed for the 10 river basins using Water and Sewerage Board data, population projections, and different assumptions concerning water treatment capacity (consumptive use).

Per capita use rates for the six communities with available data were held constant at the 1990 levels. These rates were applied to the projected year 2000 and year 2030 populations of these communities to determine total future water demands. Per capita use rates for the remaining communities were assumed to be 235 liters per day.

The low projections were prepared using the following assumptions.

- It was assumed that the national goal to make farming a more profitable enterprise would be fully realized. This would have the effect of reducing migration to the urban areas, thereby slowing urban growth to less than 2.5 percent per year. This projection was also based on the low population projection which assumes a reduction in the present fertility rate.

- It was assumed that a high percentage of all urban residents (more than 90 percent) would receive water from the community water supply system.

- It was assumed that an increasing percentage of all urban residences would be connected to the community sewer system; this would reduce the consumptive use to about 30 percent of total demand by the year 2030.

The medium projections were developed using the following assumptions.

• It was assumed that migration to the urban areas would continue unchecked and that the development of water supply facilities would not keep pace with population growth. The percentage of urban residents who would receive water from the community water supply system would, therefore, decrease to about 75 percent by the year 2030.

• It was assumed that expansion of water treatment facilities would be expanded at a rate sufficient to keep the present consumptive use rate constant.

The high projections were developed using the following assumptions.

• It was assumed that the migration to the urban areas would continue unchecked as in the medium projection but that the development of water supply facilities would be able to keep pace with this growth.

• It was assumed that consumption use as a percentage of total demand would remain constant.

The three sets of projections for municipal and industrial water use are presented in table R-9 for each basin.

A comparison of water use-versus-annual surface waterflow in each basin shows that municipal and industrial water use represents a significant portion of total flow only in the Little Usutu river basin. The Mbabane-Manzini urban corridor is located in this basin. Future water resources planning in the Little Usutu basin should consider the potential water supply requirements of the urban corridor.

Table R-9
Projected Municipal and Industrial Water Use
(mcm per year)

Basin	Low 1985	Low 2000	Low 2030	Medium 1985	Medium 2000	Medium 2030	High 1985	High 2000	High 2030
Lomati	0	0	0	0	0	0	0	0	0
Komati	0.3	0.4	0.4	0.4	0.7	0.8	0.5	0.8	0.9
Mbuluzi 1/	2.3	2.5	3.0	2.4	2.8	4.0	2.4	2.9	4.5
Little Usutu	1.9	3.6	8.3	3.1	6.6	17.6	3.4	7.2	22.1
Usutu	0.3	0.4	0.5	0.4	0.6	0.9	0.4	0.6	1.1
Ngwempisi	0.03	0.03	0.04	0.03	0.04	0.07	0.05	0.05	0.1
Mkondo	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ngwavuma	0	0	0	0	0	0	0	0	0
Pongola	0.1	0.2	0.2	0.3	0.4	0.4	0.3	0.4	0.5
Tembe 2/	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	5.23	7.43	12.74	6.93	11.44	24.07	7.35	12.25	29.5

1/ Includes 2.0 mcm per year diverted to Mbabane in the Little Usutu basin

2/ Fixed service area

RURAL DOMESTIC AND LIVESTOCK WATER DEMANDS AND USE

RURAL DOMESTIC

Water used by rural households is seldom returned to surface flows. Water demand and consumptive use are considered equivalent. Design parameters for rural water systems in Swaziland suggest that average per capita water use ranges from 25 to 35 liters per day for those households which are connected to a water system. For those households which are not connected to a water system, i.e., those households that must haul water in buckets, the per capita water use is about 5 liters per day.

Considerable efforts have been ongoing in recent years to supply piped water to rural households around the country. Projections of rural domestic water use were made using the rate at which it is assumed that rural households will be connected to potential water supply systems and using the three sets of population projections.

The low projection is based on the high population projection presented in the Population Section and assumes the present high population growth rate will continue unchecked. Under this condition, it is assumed that development of rural water systems would be slowed by complications brought about by a large population and that the percent of the population served would never exceed 15 percent. Most households would have to haul water in buckets, and average per capita demand would, thus, be low. The low percent of the population served, representing a small number of people, results in the lowest water demand projection.

The medium projection was developed using the medium population projection and assuming that the percent of population served by rural

water systems would gradually increase to reach 50 percent of the total population by the year 2030.

For the high projection, total population was assumed to be lower than the low projection presented in the Population Section. Development of rural water systems was assumed to be expedited by a small population size. By the year 2000, 50 percent of the population would have piped water and 100 percent would be served by the year 2030. Average per capita demand would be high. The high percent of the population served, representing a large number of people, results in the highest water demand projection.

Rural domestic water demand projections are presented in table R-10.

A comparison of rural domestic water use with annual surface waterflow for each basin indicates that rural domestic water use represents a very small portion of annual flow. An analysis of the year 2030 high projection was made to determine the impacts that would occur if per capita daily demand were to approach or equal the per capita daily demand for rural domestic use in the United States. This analysis shows that total water use could increase by a factor of 10. If this were to occur, rural domestic water use could represent a significant proportion of total annual flow.

LIVESTOCK

Cattle are the only livestock that significantly affect consumptive water use in Swaziland. For the medium projection, the cattle water demands are based on the assumption that the number of cattle will increase at the same annual rate as in the period from 1973 to 1977, or about 1.3 percent per year. Per capita consumption is assumed to be 30 liters per day. The low and high projections are 75 percent

Table R-10
Projected Rural Domestic Water Demands
(mcm per year)

Basin	Low 1985	Low 2000	Low 2030	Medium 1985	Medium 2000	Medium 2030	High 1985	High 2000	High 2030
Lomati	0.06	0.13	0.20	0.07	0.16	0.36	0.11	0.23	0.52
Komati	0.12	0.27	0.44	0.15	0.34	0.78	0.23	0.49	1.11
Mbuluzi	0.14	0.38	0.89	0.18	0.47	1.59	0.27	0.69	2.26
Little Usutu	0.10	0.37	0.91	0.12	0.46	1.63	0.18	0.67	2.32
Usutu	0.36	0.87	1.67	0.44	1.08	2.99	0.67	1.58	4.30
Ngwempisi	0.07	0.17	0.33	0.09	0.21	0.59	0.13	0.31	0.84
Mkondo	0.08	0.17	0.27	0.09	0.21	0.49	0.14	0.30	0.70
Ngwavuma	0.14	0.32	0.51	0.17	0.40	0.92	0.27	0.58	1.31
Pongola	0.09	0.21	0.34	0.12	0.26	0.60	0.18	0.38	0.86
Tembe	0.01	0.04	0.08	0.01	0.05	0.14	0.02	0.07	0.19
Total	1.17	2.93	5.64	1.44	3.64	10.09	2.20	5.30	14.41

and 125 percent, respectively, of the medium projection. Projected cattle water demands are presented in table R-11.

INDEPENDENT INDUSTRIAL WATER DEMANDS

This section contains a discussion of the present and future industrial water demands in Swaziland. Only the major industrial abstractors that use their own sources rather than water from a municipal supply are itemized.

Industrial consumptive use in Swaziland is quite insignificant compared to the quantities available and the large consumption of irrigation. Table R-12 presents the industrial water demands under existing conditions.

As shown in table R-12, consumptive use makes up a very small portion of total demand (about 2.5 percent). Of the total water demands of 627 mcm, hydroelectric generation demands account for 591 mcm; this nonconsumptive demand represents nearly 95 percent of the total.

FUTURE INDUSTRIAL WATER DEMANDS

The extent of future industrial expansion in Swaziland is highly uncertain. A discussion of possible future industrial expansion, in the 1978 Merz and McLellan Report, indicated some industrial development plans. For purposes of estimating future industrial water demands, it

Table R-11
Projected Cattle Water Demands
(mcm per year)

Basin	Low			Medium			High		
	1985	2000	2030	1985	2000	2030	1985	2000	2030
Lomati	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.4	0.5
Komati	0.7	0.8	1.1	0.9	1.0	1.5	1.1	1.3	1.9
Mbuluzi	1.1	1.3	2.0	1.4	1.7	2.6	1.8	2.1	3.3
Little Usutu	0.4	0.5	0.7	0.5	0.6	0.9	0.6	0.8	1.1
Usutu	1.7	2.0	3.0	2.3	2.7	4.0	2.9	3.4	5.0
Ngwempisi	0.4	0.5	0.7	0.5	0.6	0.9	0.6	0.8	1.1
Mkondo	0.4	0.5	0.7	0.5	0.6	0.9	0.6	0.8	1.1
Ngwavuma	0.5	0.6	0.9	0.7	0.8	1.2	0.9	1.0	1.5
Pongola	0.4	0.5	0.7	0.5	0.6	0.9	0.6	0.8	1.1
Tembe	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5
Total	6.0	7.1	10.4	7.8	9.2	13.7	9.8	11.8	17.1

Table R-12
Current Annual Industrial Water Demands

River	Total Demand (cms)1/	Total Demand (mcm)	Consumptive Use (mcm)	Name of Water Abstractor
Lomati	1.7 2/	55	0	Ngonini Estates Hydro Generation
Komati	0.1	2	2	Mhlume Sugar Corp.
Mbuluzi	0.2	6	6	Royal Swazi Sugar Corp.
Little Usutu	10.9 2/	357	0	Swaziland Electricity Board Hydro Generation
Great Usutu	0.7	23	4	Usutu Pulp Company
	5.4 2/	179	0	Swaziland Electricity Board
	0.1 3/	1	0	Libby's Factory at Malkerns
	0.1	4	4	Ubombo Ranches
Total	19.2	627	16	

1/ Cubic meters per second

2/ These represent maximum values

3/ Less than 0.1

Source: Ministry of Works, Power and Communications

will be assumed that plans discussed in that report will be implemented. These industrial development plans include the following:

- expansion of the Usutu Pulp Company - Great Usutu;
- a vegetable oil plant in Nsoko - Ngwavuma;
- a cotton spinning and weaving mill in Nhlangano - Ngwavuma;
- a tannery at Matsapha - Great Usutu; and
- the processing of molasses into industrial alcohol at one of the sugar processing plants - Mbuluzi.

Table R-13 shows the projected future increase in industrial water demands based upon the industrial expansion plans outlined above. Where existing industrial water use data were not useful for projecting the future additional demands, the 1974 National Bureau of Economic Research/ Harvard University report was used as a reference.

Table R-13
Future Additions to Industrial Water Demands
by the Year 1990

River	Total Demand (mcm)
Mbuluzi	0.9
Ngwavuma	2.2
Great Usutu	9.3

The references used in this section are 2, 3, 5, 13, 22, 47, and 78, as listed in Section T.

SECTION S

DAMSITE SCREENING

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DAMSITE SCREENING

Swaziland is endowed with numerous potential damsites. Potential damsites have been studied and identified in several earlier reports dating from 1955. Most of this work was summarized in the 1970 United Nations Development Program (UNDP) Report. A comprehensive list of damsites which had been identified prior to the 1970 UNDP Report is contained in table 2.2-1 of that report. The UNDP Report study team reviewed and narrowed the comprehensive list to 57 damsites which are listed by river in table 2.3-1 of that report. The 1970 UNDP Report did not include the Ngwavuma river. The screening of reservoir sites in the Ngwavuma basin is included in the 1977 Ngwavuma Report.

Damsites previously selected were screened, for this study, by considering factors such as the best location for maximum river control, reservoir storage capacity, storage-to-embankment-volume relationship, topography, relocations, and present land use of reservoir areas. A review of geologic maps and a brief field reconnaissance were conducted for most damsites.

Seventeen damsites were selected for further study. These 17 selected damsites are discussed by river basin in the following paragraphs and are numbered the same as in the 1970 UNDP Report and the 1977 Ngwavuma Report. Additional features and information on these damsites are contained in those reports. The damsites, which are evaluated in the Plan Formulation Section of Part I, are shown on plate 8. Future studies should consider all available damsites because it is most likely that alternative locations within short reaches could be used. Prior to final design, a detailed geotechnical study including exploratory borings and testing would be required. Detailed surveys would also be required to determine the best dam sizes and locations.

Pertinent area-capacity curves are shown in figures S-1 through S-14, which follow the text material in this section. These curves are for preliminary planning purposes only. Detailed mapping with appropriate scale and contour intervals would be required for detailed planning. The dam volume curves are based on the assumption that the dam height would be 3 meters above the top of the active water supply storage level. The required dam height is a function of the spillway design flood, antecedent reservoir conditions, and the spillway size. Detailed planning is required to study these variables and determine the optimum dam height-spillway size combination.

LOMATI

Only one damsite (DS) in the Lomati basin was selected for consideration.

DS 5.2

The portion of the Lomati basin in Swaziland is relatively short and the lower reach is already used for irrigation schemes. DS 5.2 would provide control of the Lomati river and would contain about twice the capacity of DS 5.1, which was not selected for further study. A dam with a crest elevation of about 475 meters above mean sea level (m.s.l.) appears practical. The topographic high on the right bank is considered to limit the height. There is some alluvium in the riverbed and there may be bands of chert and quartzite in the left abutment. A damsite approximately 0.7 kilometer (km) upstream may be better geologically, but the substantial storage and runoff available from a major tributary stream would not be used.

KOMATI

The Komati river is longer than the Lomati river in its course through Swaziland. Two damsites have been selected for further study, DS 6.2D and DS 6.5. DS 6.1, DS 6.2, DS 6.3, DS 6.4, and DS 6.6, which are included in the 1970 UNDP Report, were excluded from consideration for this report because of their lesser storage-to-embankment-volume relationship. DS 6.7, DS 6.8, and DS 6.9 were not considered further because large areas of arable land would be inundated and a large number of people and numerous facilities would have to be relocated.

DS 6.2D

This damsite was not included in the 1970 UNDP Report; it was first identified in this current study. It would be located downstream from DS 6.2, which was included in the 1970 UNDP Report, and just upstream from the new Piggs Peak road bridge. It would be near hydropower station 6.1. A dam with a crest elevation of 686 meters m.s.l. is considered preferable because a reservoir higher than this would probably flood an asbestos mine in the Republic of South Africa. The country rock is granite at this location and is exposed in the river bottom as well as in outcrops visible on both abutments.

DS 6.5

DS 6.5 is suitable for a relatively high dam with a crest at elevation 488 meters m.s.l. Rock is exposed in the river and on both abutments. Fracturing is evident in the granite but appears to be tight. A dam with a crest at about elevation 442 meters m.s.l. could be located at a narrower river section approximately 0.5 km upstream. Suitable borrow appears to be located upstream on the right bank around the nose of the right abutment location.

DS 7.1 (MKOMAZANE)

There are three potential damsites along an approximate 2-km reach of the Mkomazane river. The damsite included in the 1970 UNDP Report would be the farthest upstream. A second damsite could be located approximately 1 km downstream from this damsite, and a third damsite approximately 1 km farther downstream. Downstream from the third damsite, the river gradient is steeper and the storage capacity declines rapidly. An elevation of 747 meters m.s.l. was selected for the dam height of all three sites. These dams, however, could be higher if sufficient water were available and if more storage were required.

DS 7.2 (MLAMBONGWENYA)

The Mlambongwenya river is located directly north of the Mkomazane river. DS 7.2 characteristics are very similar to those of DS 7.1. A crest elevation of 747 meters m.s.l. was also selected for this damsite. Foundation conditions also appear to be very similar to those described for DS 7.1 in the 1970 UNDP Report. This damsite could accommodate a higher dam if sufficient water were available and if more storage were required.

DS 7.3 (MZIMNENE)

Of the three potential damsites along the lower reaches of the Mzimnene river, the most promising damsite selected for study in this report would be located approximately 1.5 km upstream from the road crossing at Fullerton. It would have a crest elevation of 366 meters m.s.l. and would provide substantial storage. Rock is not exposed at

this site, but indications are that it is very near the surface. Granite is exposed in the stream bottom at the bridge crossing downstream from the damsite. This location is considerably downstream from a second potential damsite which was indicated in the 1970 UNDP Report; that damsite would have a small storage capability. A third potential damsite is approximately 2.5 km upstream from the road crossing; it would have a crest elevation of 381 meters m.s.l.

MBULUZI

DS 8.4 is the only damsite selected for analysis. The other damsites shown in the 1970 UNDP Report (DS 8.1, DS 8.2, and DS 8.3) would not provide as much control and would have less storage and a less attractive storage-to-embankment-volume relationship.

DS 8.4

DS 8.4 would have good storage capabilities and is located where it could supplement the control exercised by the existing Mnjoli dam. The crest height would be limited to about elevation 643 meters m.s.l. by existing topography. Additional height could be attained with the use of saddle dikes.

LITTLE USUTU

Screening was not done for the Little Usutu river because advance planning for the Luphohlo-Ezulwini Hydroelectric Scheme (DS 0.1 of the

1970 UNDP Report) and for the Lozitha dam (DS 0.2 of the 1970 UNDP Report) is underway. For this report, it is assumed that these two dams will be constructed with DS 0.1 having a gross capacity of 24 million cubic meters (mcm) and DS 0.2 having a gross capacity of between 47 and 50 mcm.

UPPER GREAT USUTU

Three damsites were identified in the 1970 UNDP Report. Only one, DS 1.3, was selected for further study.

DS 1.3

DS 1.3 was selected for further study because of its good storage and storage-to-embankment-volume characteristics. A dam with a crest height at elevation 838 meters m.s.l. was selected because of the topography on the right bank. DS 1.3 and DS 1.2 are only about 5 km apart; during any future detailed studies, both should be considered and the optimum site selected. DS 1.3 was identified but not discussed in the 1970 UNDP Report; most of the information included for DS 1.2, however, is applicable to DS 1.3. An upstream damsite, DS 1.1, was excluded because it would provide much less control and would have poor storage characteristics.

NGWEMPISI

Two damsites on the Ngwempisi river were included in the 1970 UNDP Report. DS 2.2, the most downstream damsite, was selected for additional study for this report. It could provide more control and more storage than the upstream damsite, DS 2.1.

DS 2.2

A dam with a crest at elevation 838 meters m.s.l. could be constructed without requiring extensive relocations. If sufficient water were available and additional storage were required, a dam with a much higher crest elevation could be constructed; however, relocations would be required.

MKONDO

Two potential damsites were included in the 1970 UNDP Report. The upstream damsite, DS 3.1, was excluded because it would not provide as much control as DS 3.2. In addition, the reservoir area at DS 3.1 would inundate the Ricelands area, which is already irrigated, and other potential arable lands.

DS 3.2

A dam with a crest at elevation 350 meters m.s.l. could be constructed with some minor road relocations to the main unpaved road on

the right bank. If sufficient water were available and if additional storage were required, DS 3.2 could accommodate a higher dam; however, a major road relocation would be required.

LOWER GREAT USUTU

Four damsites were identified in the 1970 UNDP Report. Only DS 1.8 was selected for further study. DS 1.5, DS 1.6, and DS 1.7 were all excluded from the current study because of poor site characteristics, major relocation requirements, and flooding of potential arable land.

DS 1.8

DS 1.8 is the most suitable downstream damsite on the Lower Great Usutu river. A dam with a crest at elevation 308 meters m.s.l. was presented in the 1970 UNDP Report. At this elevation, the railroad and marshalling yards at Sidvokodvo would be inundated. The lower power station on the Luphohlo-Ezulwini Hydroelectric Scheme includes plans for a tailrace sill at an approximate elevation of 293 meters m.s.l.; this would also be inundated. A dam with a crest at approximate elevation 260 meters m.s.l. is the maximum that could be achieved without affecting the existing railroad. This damsite appears to be more attractive as a diversion site rather than a storage site. It was, therefore, selected for further consideration only as a diversion site.

LOWER GREAT USUTU TRIBUTARIES

Six damsites were identified in the 1970 UNDP Report. Only three, DS 4.4, DS 4.5, and DS 4.6, were selected for further study.

DS 4.4 (MHLATUZANE)

DS 4.4 was studied extensively for the 1970 UNDP Report and other schemes for irrigation in southeast Swaziland and is included in this report. A dam with a crest at elevation 232 meters m.s.l., in conjunction with an auxiliary dam on the Golome Stream with the same crest elevation, could be constructed. This is the maximum elevation for this damsite because of the topography. DS 4.1, DS 4.2, and DS 4.3, all upstream damsites, were excluded from further study because of the small storage capacities and the poor storage-to-embankment-volume characteristics.

DS 4.5 (MHLATUZE)

DS 4.5 was selected for further study to provide storage in the southeastern Lowveld region. It is located near the downstream limit of the Mhlatuze river where it can provide maximum control. It also would have better storage characteristics than any smaller damsites that could be located farther upstream. The topography at DS 4.5 is very flat; consequently, this would be a relatively long, low dam. Some rock outcrops are exposed on the right bank. Rock is not exposed in the stream bottom at the damsite; however, it is exposed a short distance downstream from the highway bridge which is just a few hundred meters downstream from the damsite. No rock was visible on the left bank but probably is near the surface. Adequate borrow should be

available upstream. No information was presented for this damsite in the 1970 UNDP Report.

DS 4.6 (MZIMPHOFU)

A dam of substantial height with a large storage area could be constructed at the location shown for DS 4.6. A dam with a maximum crest elevation at about 305 meters m.s.l., however, appears most practical because, apparently, not much water is available in the basin. Access to this damsite was difficult and, at the time of field viewing, the stream was completely dry with a relatively clean sand bottom. Bedrock is exposed occasionally in the streambed jutting up through the sand. Some rock outcrops are visible on both abutments. Consideration will be given to this damsite for storage in the Lowveld region.

NGWAVUMA

There are a number of damsites on this river which would provide varying degrees of control and storage. The one selected for further consideration is located the farthest downstream where substantial height and storage could be achieved.

DS V

A comprehensive report (1977 Ngwavuma Report) has been prepared on DS V; it recommends a dam with a crest at elevation 265 meters m.s.l. It appears that a higher dam to elevation 275 meters m.s.l. would be

possible and would provide much more storage if needed. Much additional information is contained in the Draft Final Report of the 1977 Ngwavuma Report.

The references used in this section are 2 and 10, as listed in Section T.

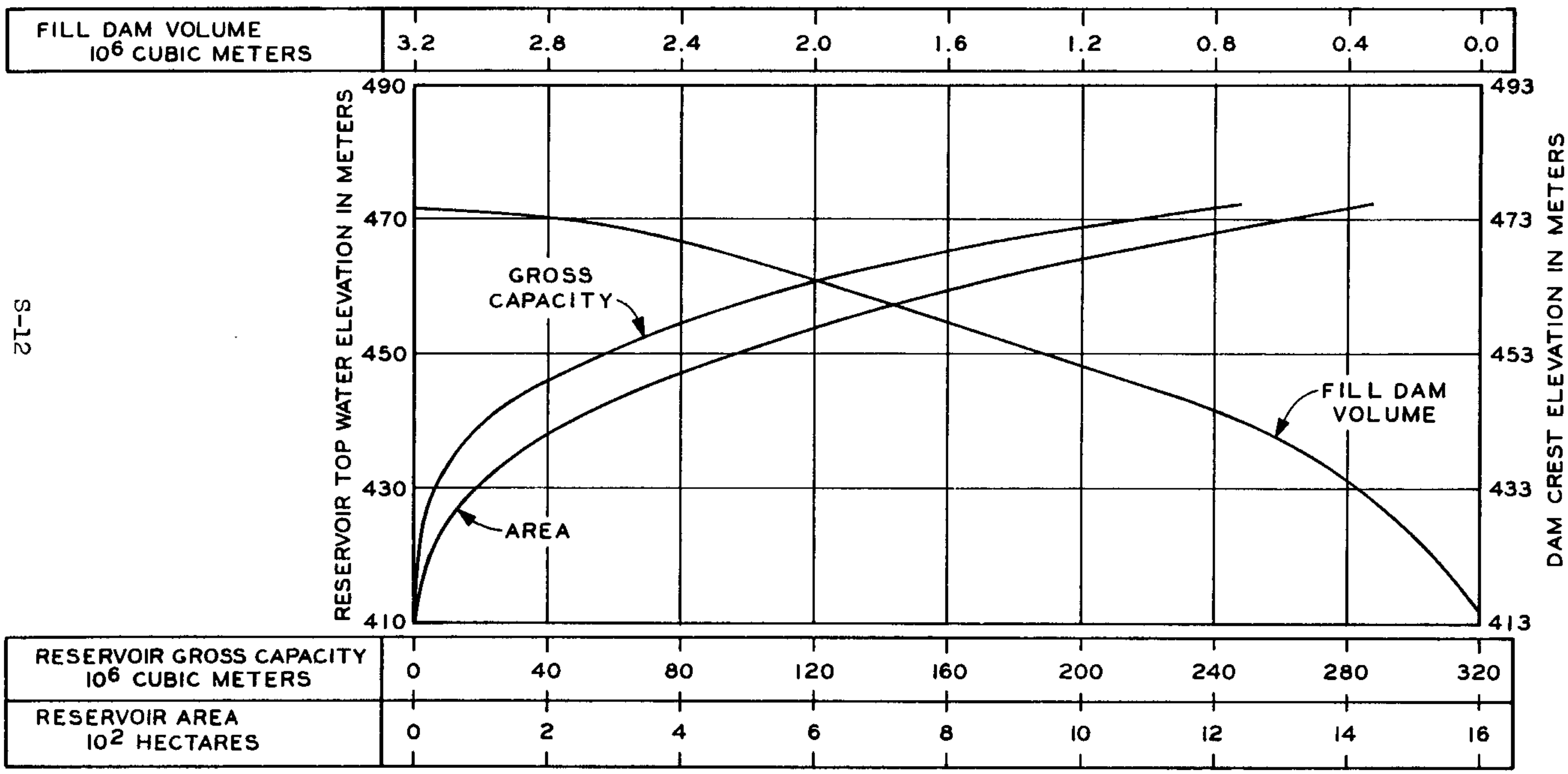

FIGURE S-1
DAM SITE 5.2
LOMATI BASIN

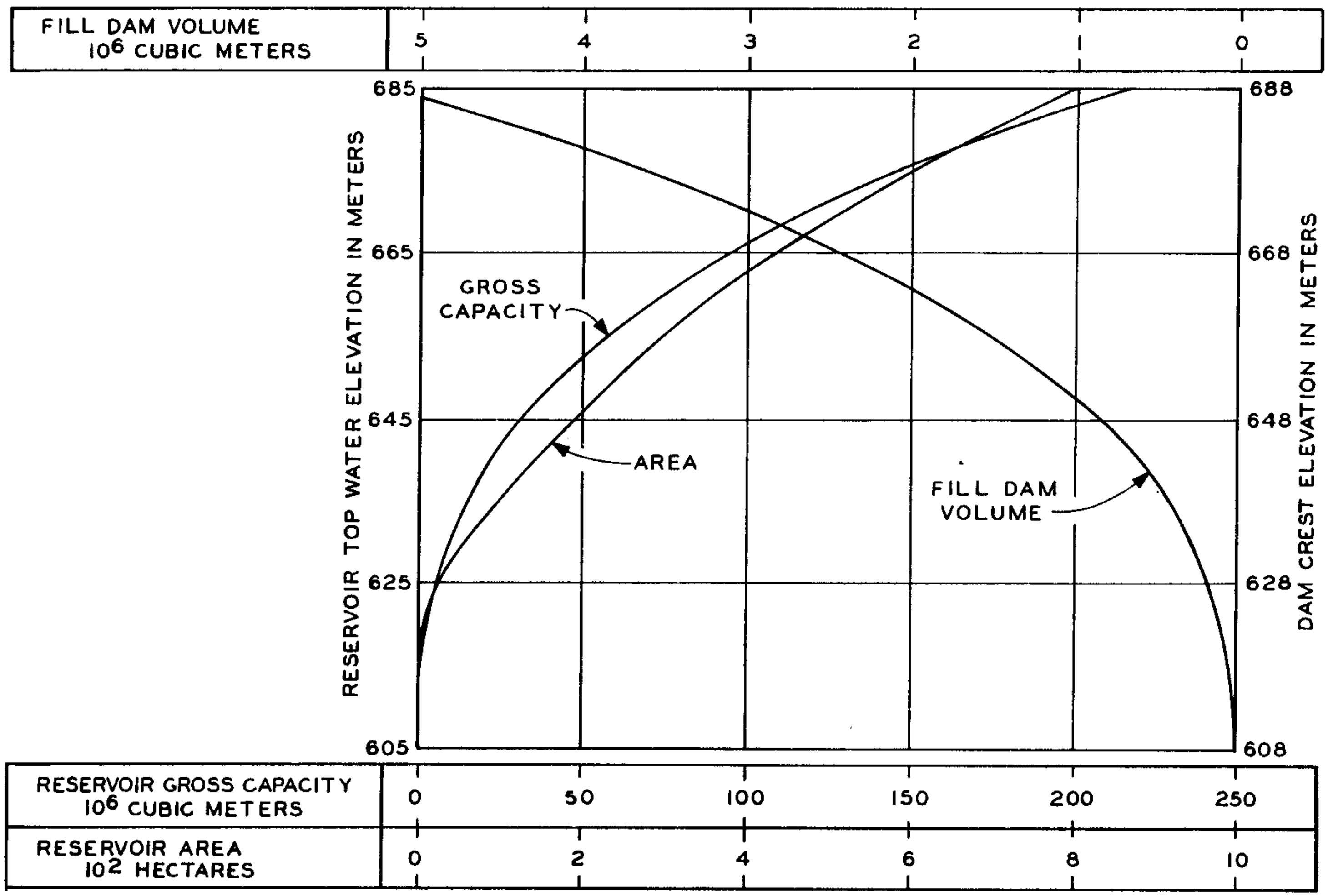

FIGURE S-2
DAM SITE 6.2D
KOMATI BASIN

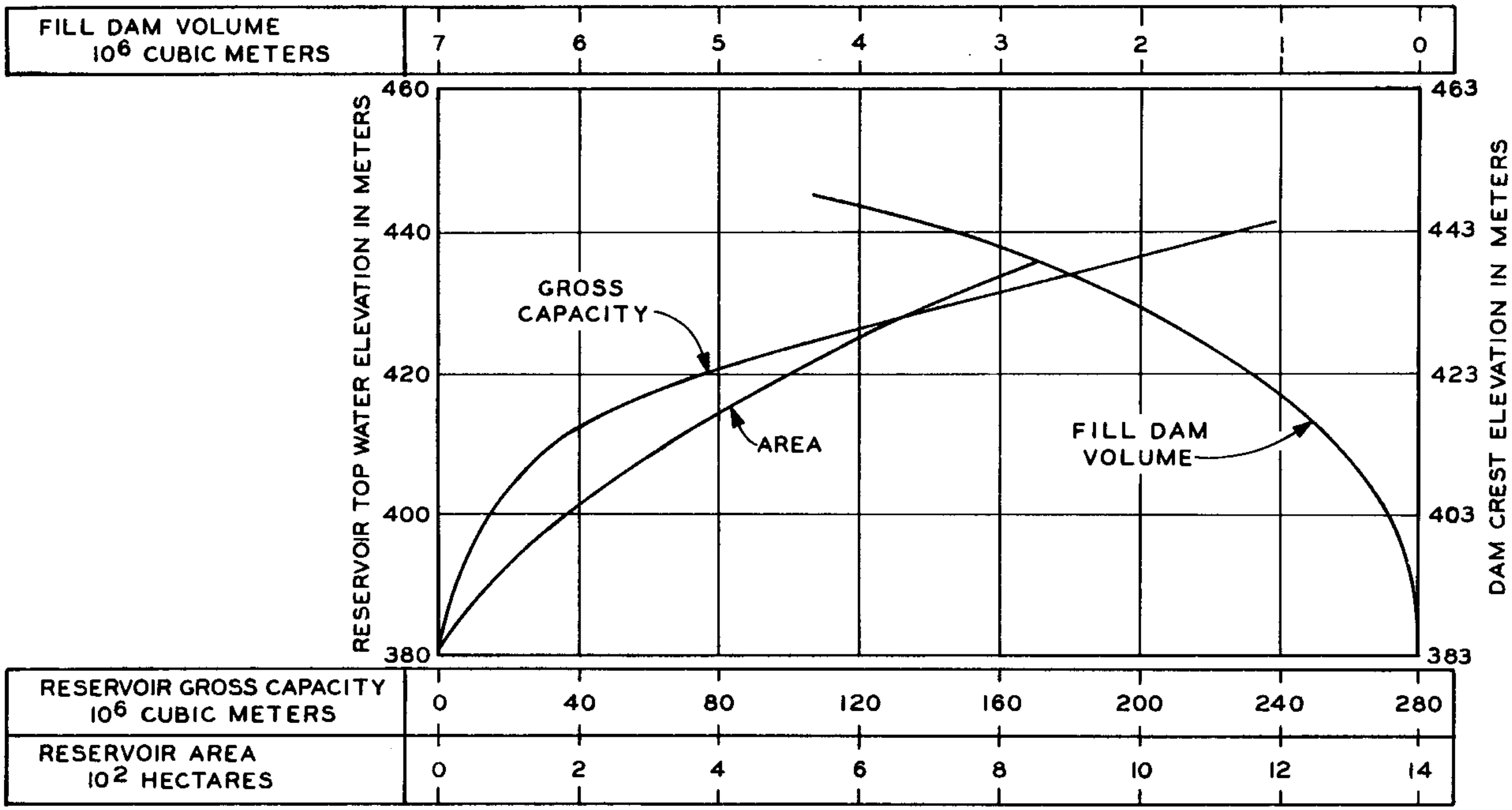

FIGURE S-3
DAM SITE 6.5
KOMATI BASIN

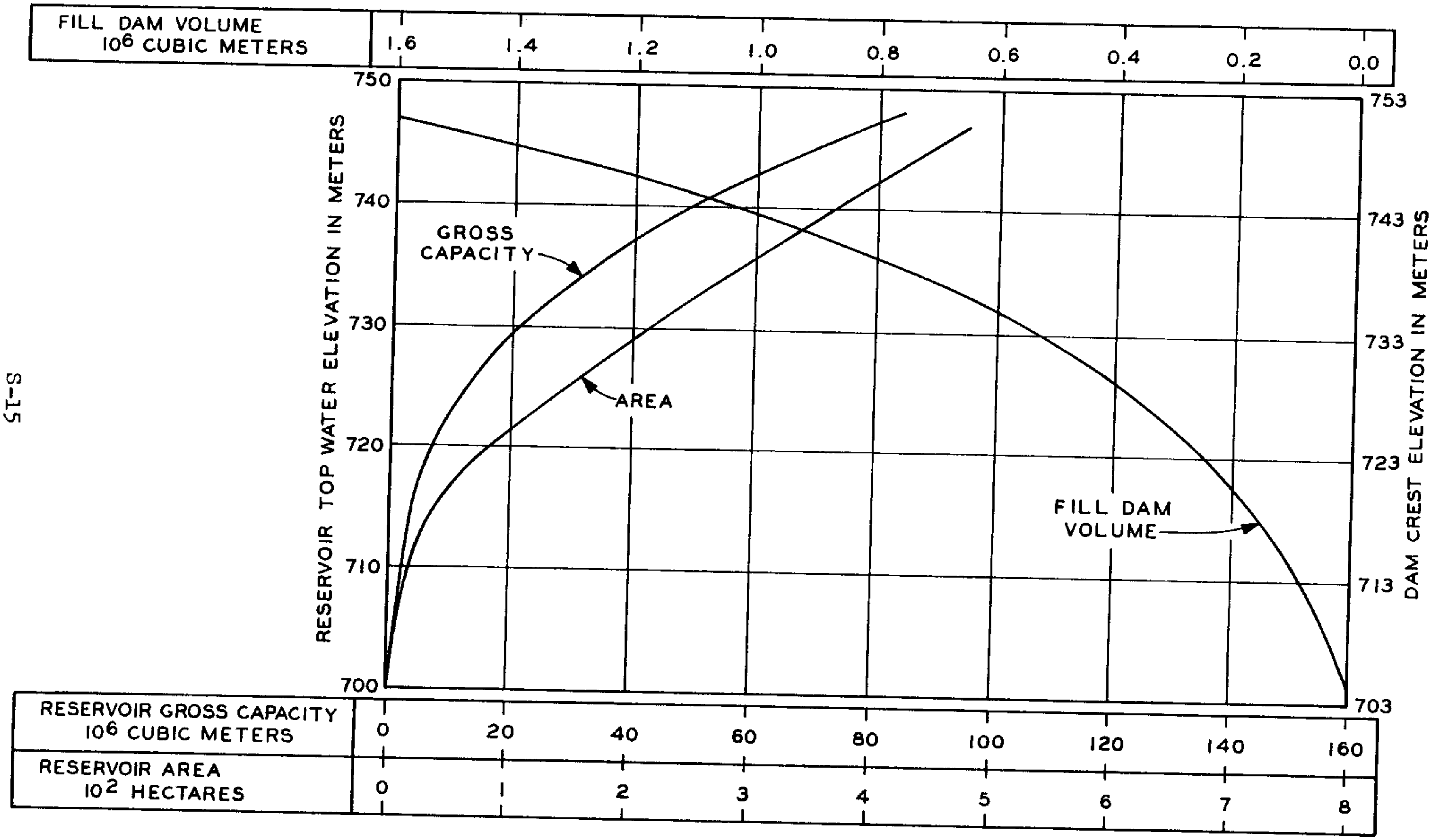

FIGURE S-4
DAM SITE 7.1
KOMATI BASIN

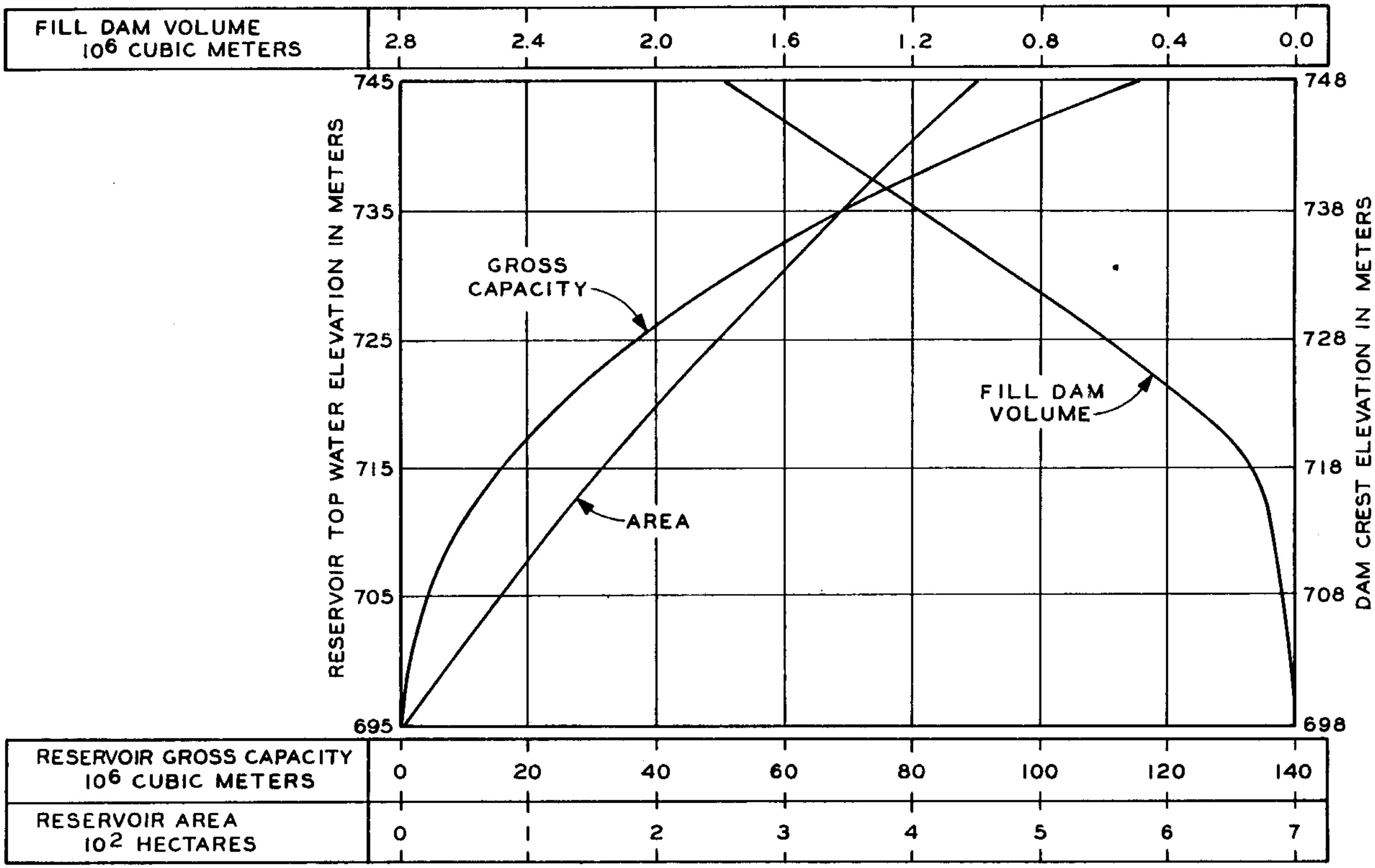

FIGURE S-5
DAM SITE 7.2
KOMATI BASIN

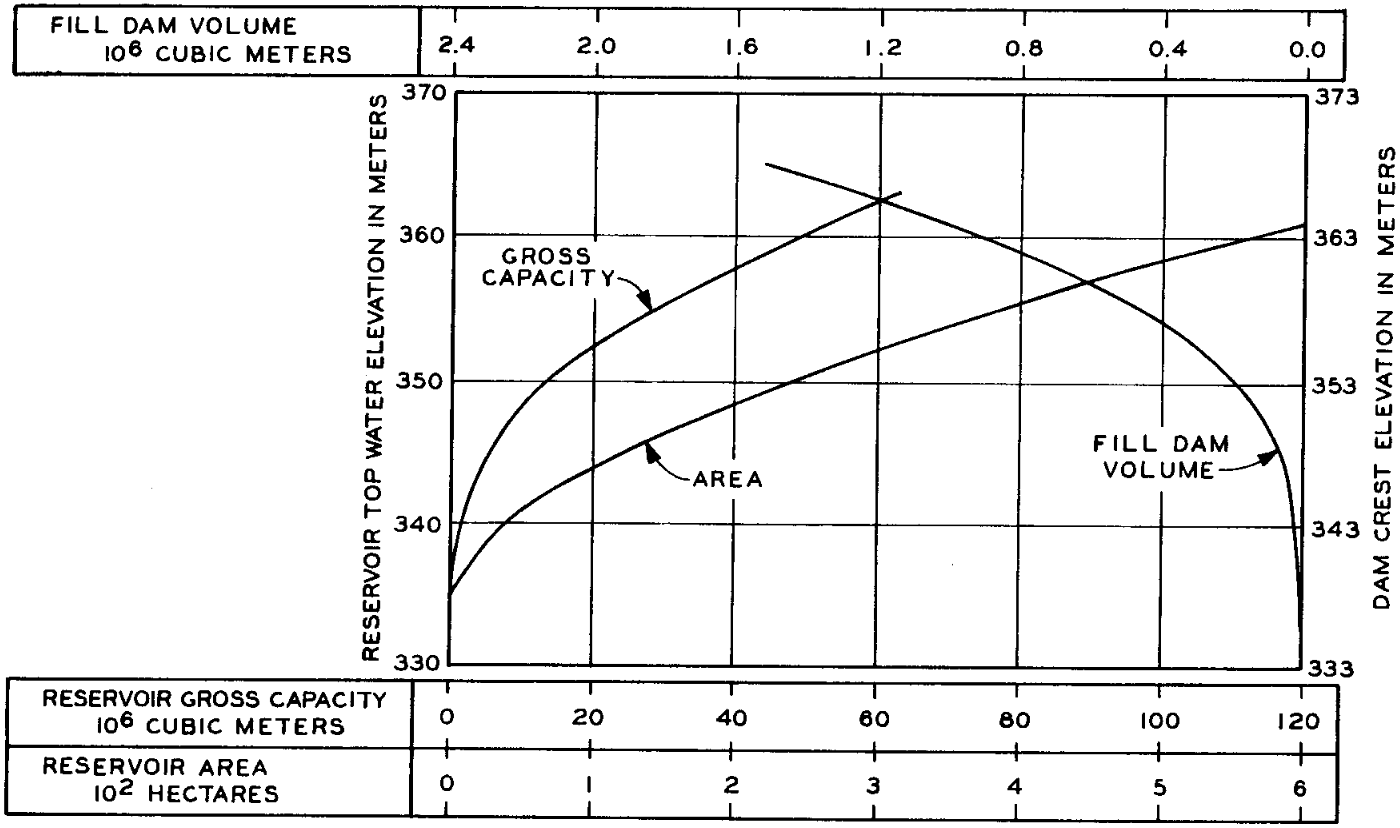

FIGURE S-6
DAM SITE 7.3
KOMATI BASIN

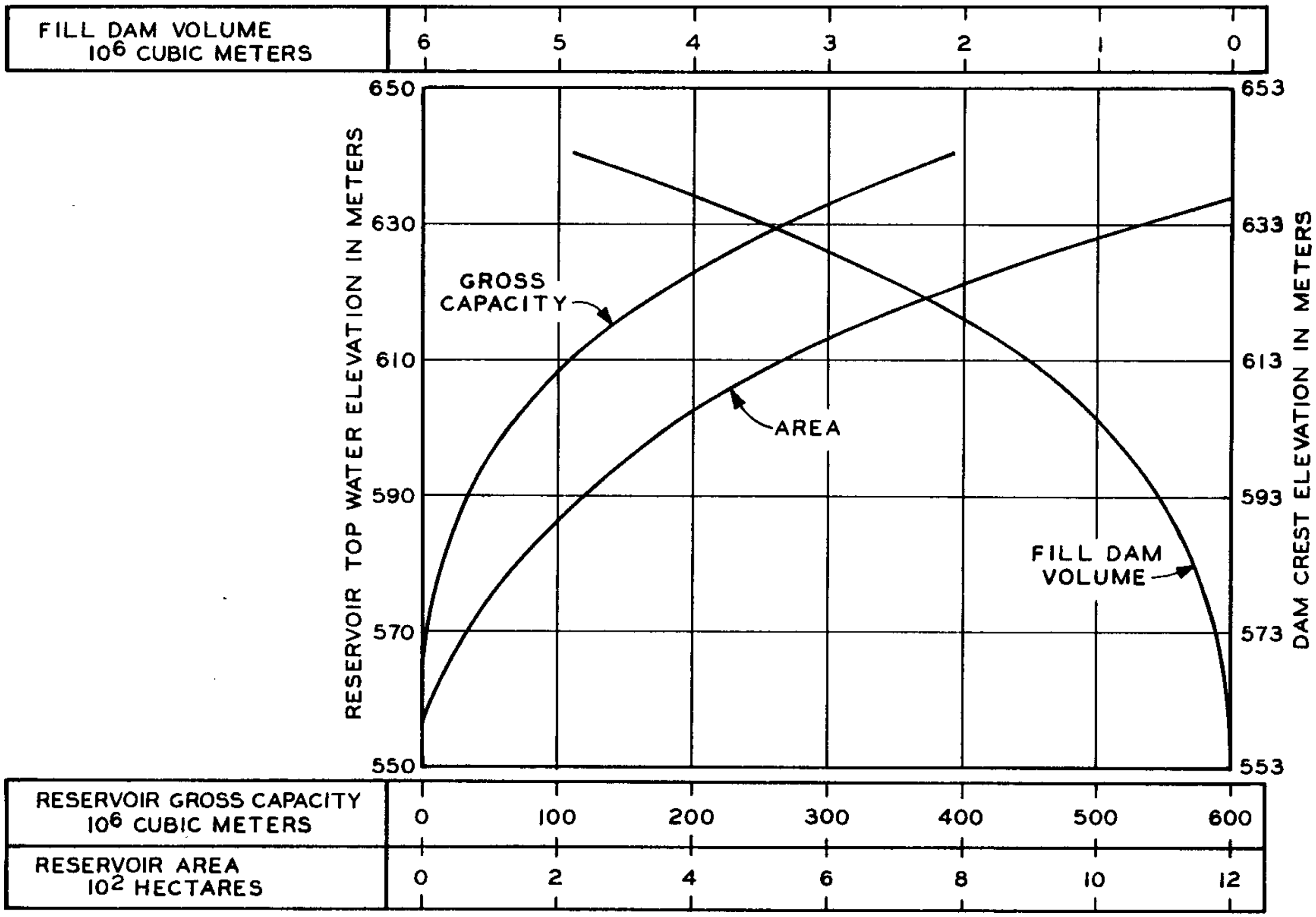

FIGURE S-7
DAM SITE 8.4
MBULUZI BASIN

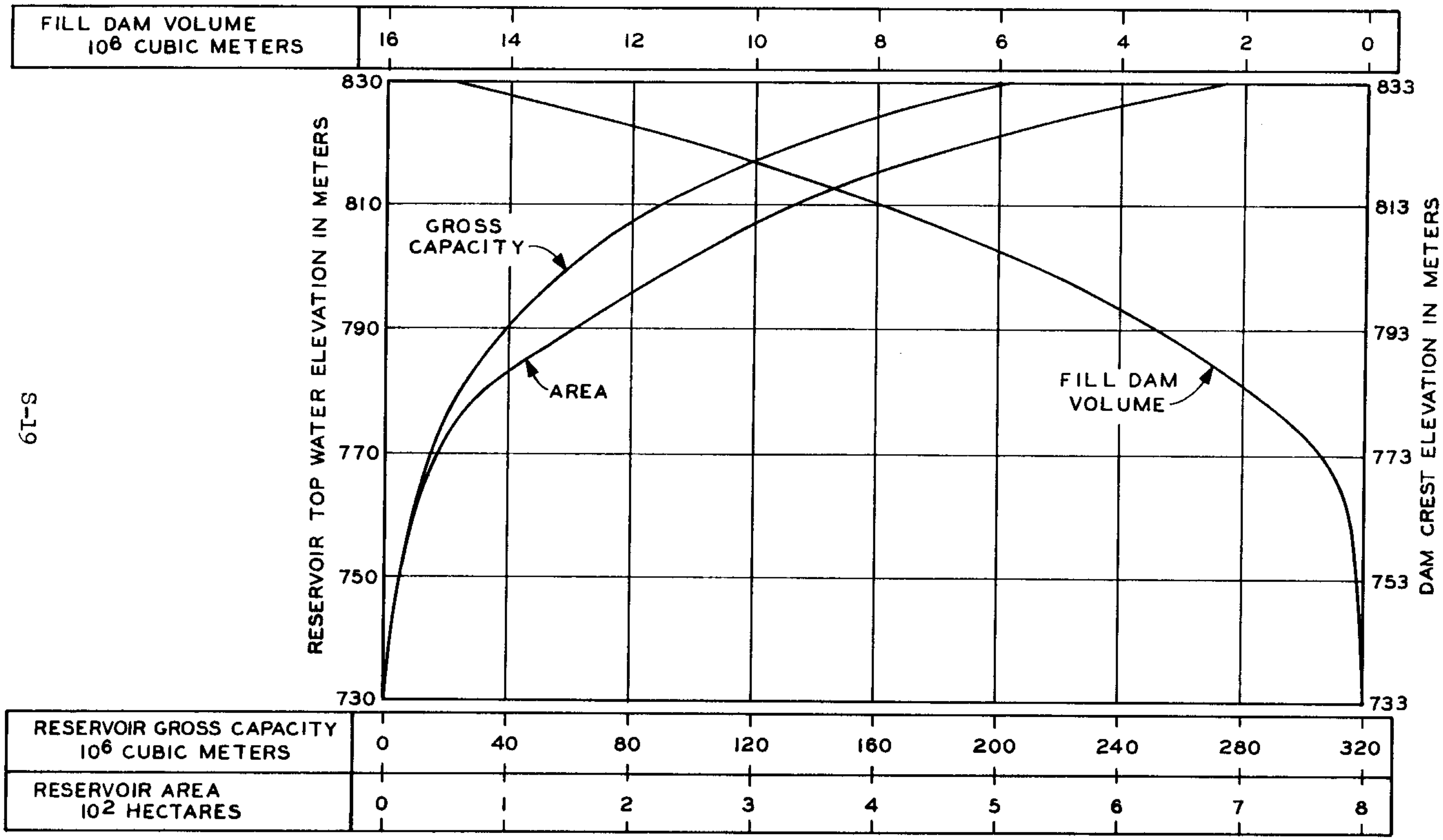

FIGURE S-8
DAM SITE 1.3
GREAT USUTU BASIN

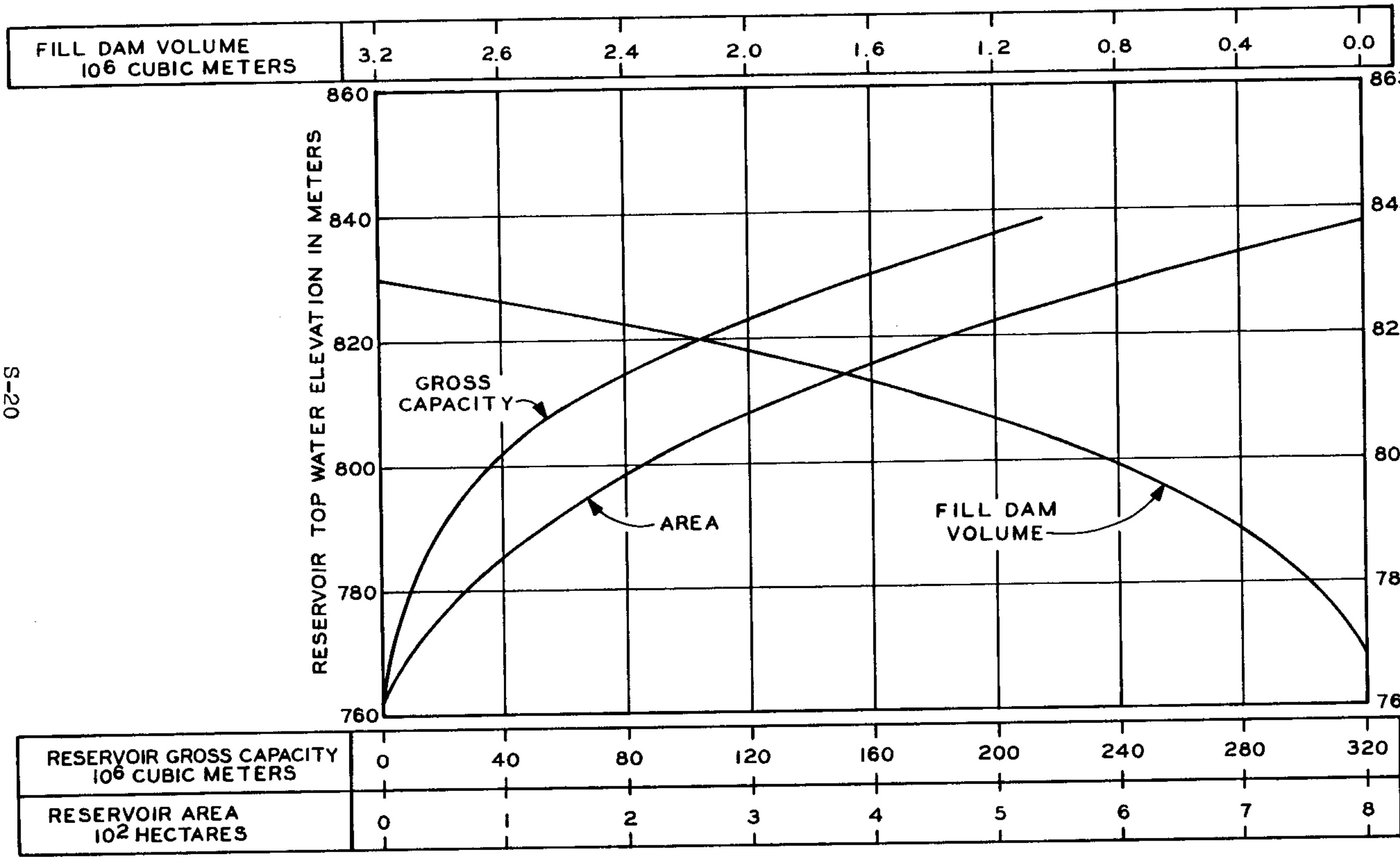

FIGURE S-9
DAM SITE 2.2
NGWEMPISI BASIN

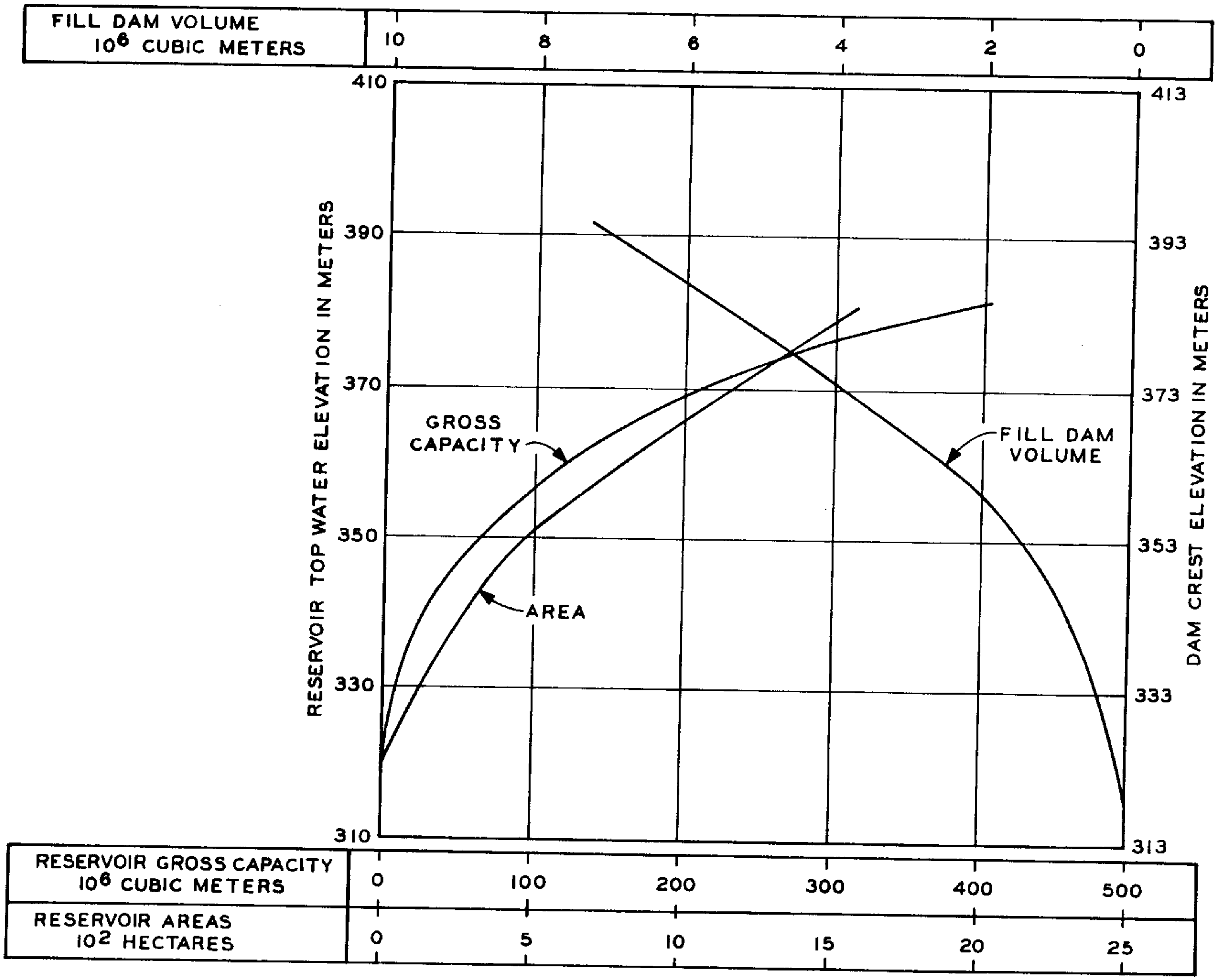

FIGURE S-10
DAM SITE 3.2
MKONDO BASIN

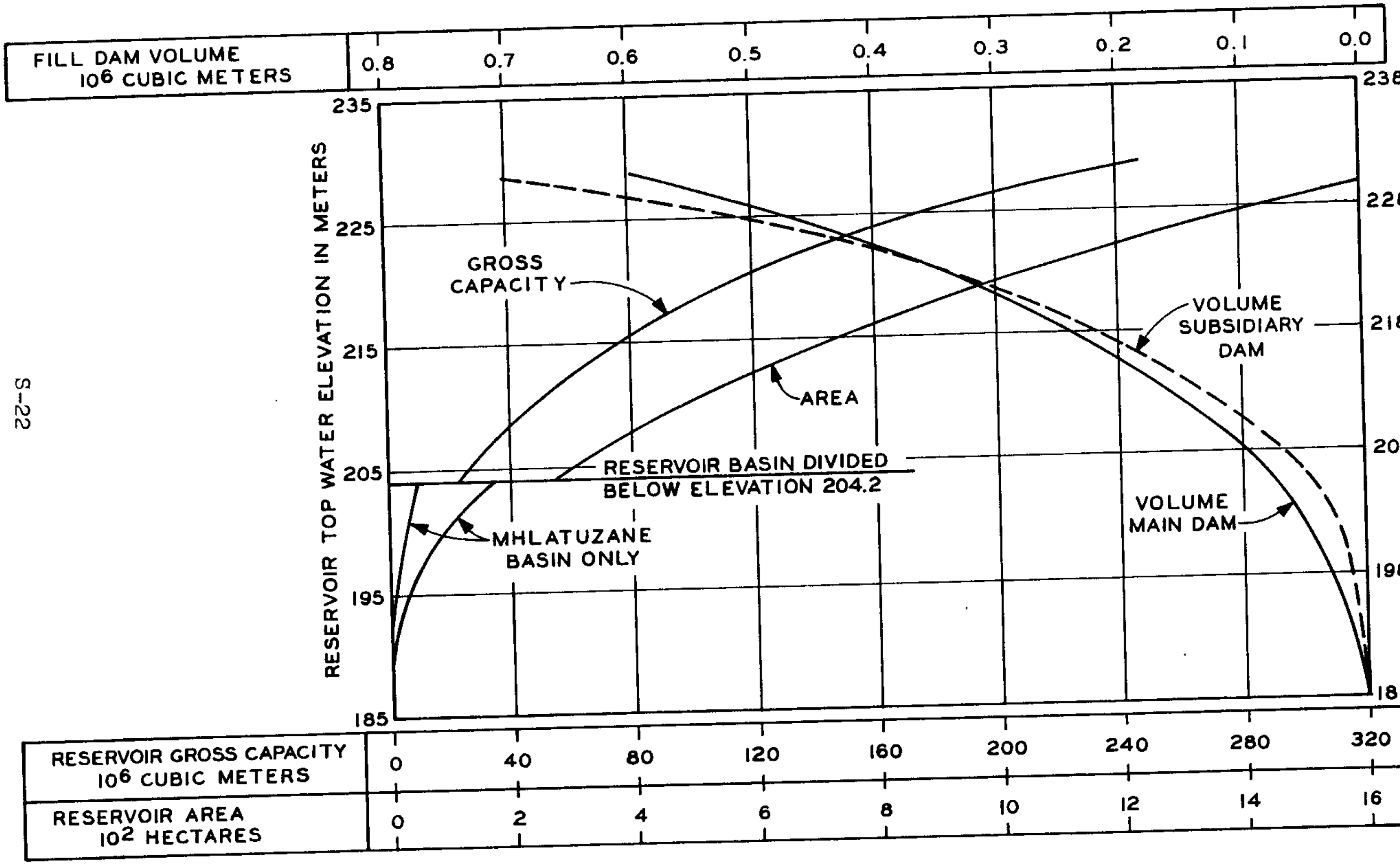

FIGURE S-11
DAM SITE 4.4
GREAT USUTU BASIN

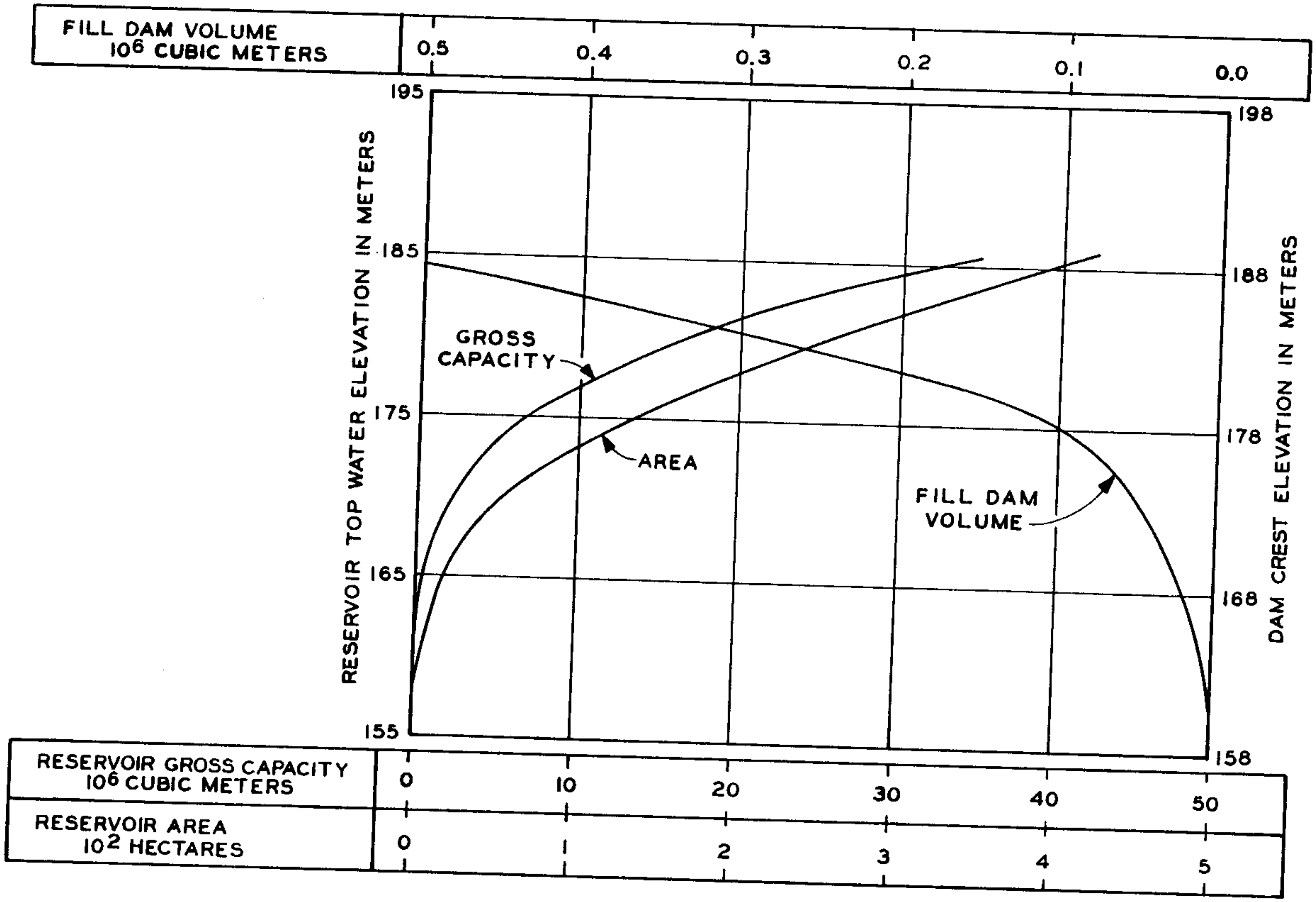

FIGURE S-12
DAM SITE 4.5
GREAT USUTU BASIN

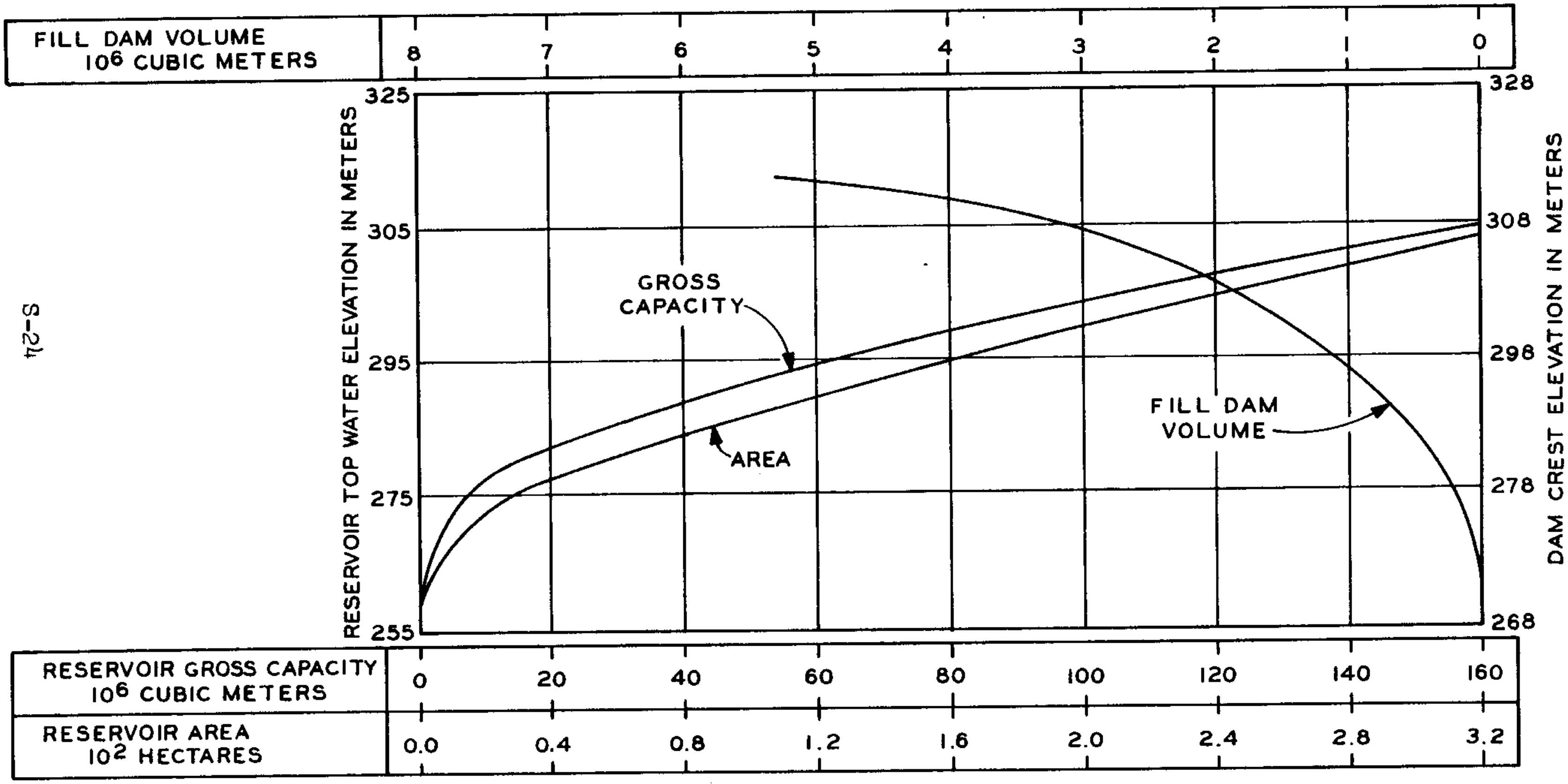

FIGURE S-13
DAM SITE 4.6
GREAT USUTU BASIN

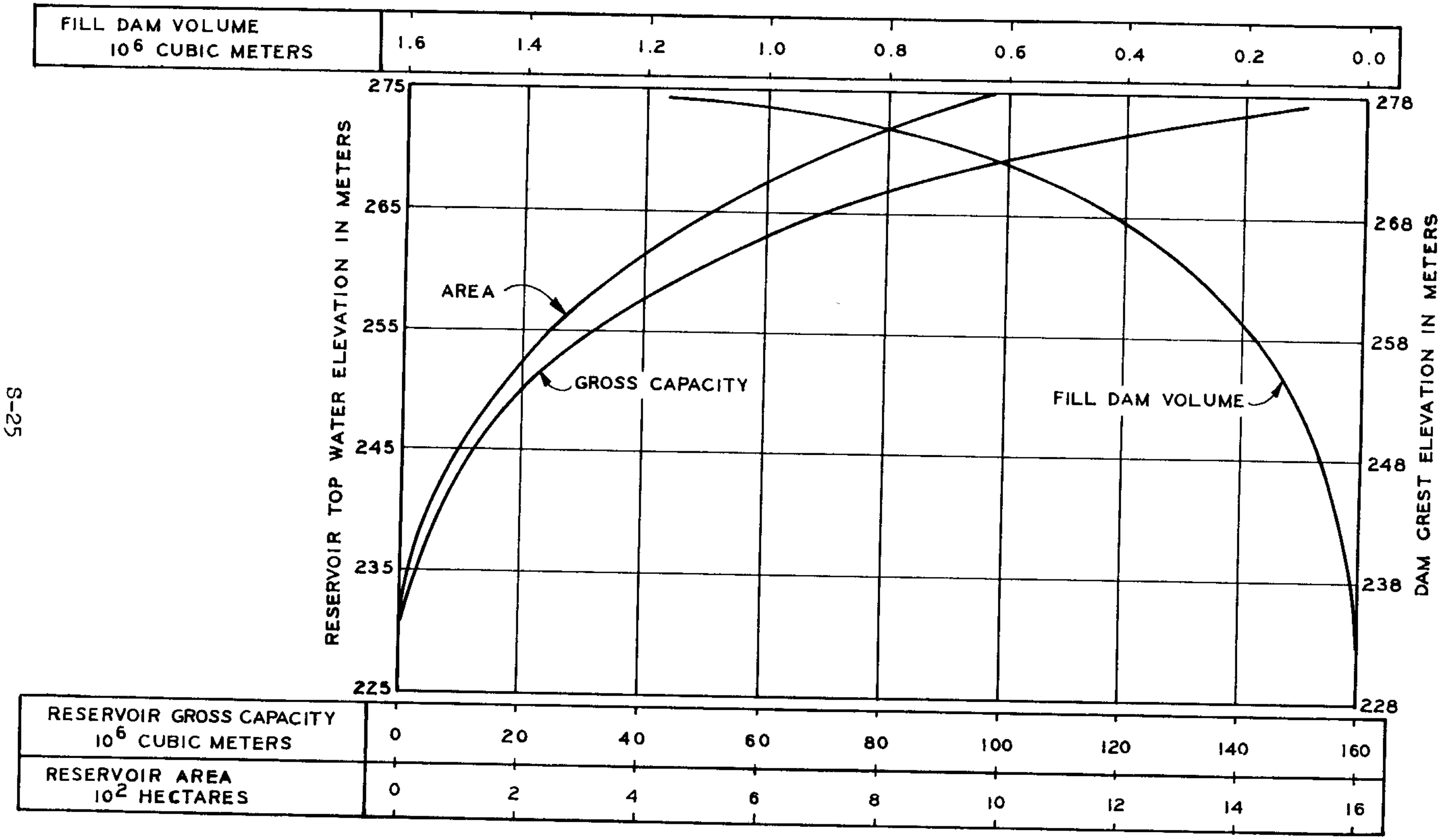

FIGURE S-14
DAM SITE V
NGWAVUMA BASIN

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    Scale 1:50,000 with 50-foot contours, 1965-1976.
    Scale 1:250,000 with 125-meter contours, 1976.

59. Swaziland River Basins Gauging Stations. Ministry of Works, Power and Communications, Water Resources Branch. Shows precipitation stations and river gaging stations.

    Scale 1:250,000, undated (after 1977).

60. Swaziland River Catchments. Ministry of Works, Power and Communications, Water Resources Branch. Unpublished. Shows border flows, existing and potential losses of catchments.

    Scale 1:500,000, undated.

61. Republic of South Africa, Swaziland and Mocambique Water Resources. Maps of Rivers with Origin in the Republic of South Africa. J. P. Kriel, Secretary for Water Affairs.

    Scale about 1:676,000, 1966.

62. Soil Map of Swaziland, with References. In Murdoch, 1970.

    Scale 1:125,000, 1970.

63. Land Capability Map of Swaziland, with References. In Murdoch, 1970.

    Scale 1:125,000, 1970.

64. Map of Rural Water Supply, with Reference. Ministry of Works, Power and Communications, Water and Sewerage Board.

    Scale 1:250,000.

65. Swaziland Census Project Map (1975/76), with References. Ministry of Works, Power and Communications, Water and Sewerage Board. Shows existing water supply services and population with access to water supply.

    Scale 1:250,000.

66. Protectionworthy Areas, with references. In Reilly, 1979.

Scale 1:50,000, with 50-foot contours, 1965 and 1976.
Scale 1:250,000, with 125-meter contours, 1976.

67. Orthophoto Maps. Through Surveyor General and Ministry of Agriculture.

Scale 1:5,000, ongoing production.

68. Joint Operations Graphic (Air), Series 1501. Army Map Service, Corps of Engineers, Washington, D.C.

Scale 1:250,000, with 165-foot contours, 1966.

69. Geological Map of Swaziland. Geological Survey and Mines Department. Mbabane.

Scale 1:250,000, compiled by D. R. Hunter, 1966.
Scale 1:50,000.

70. Site Specific Topographical Surveys. Government of Swaziland. Contracted for specific damsites, as referenced in UNDP, 1970.

Scale: 1:10,000 (used in this study) and others.

71. Land Tenure, 1979. Ministry of Agriculture and Cooperatives, Rural Development Area Program Office.

Scale 1:250,000, 1979.

PERSONAL COMMUNICATIONS

Discussions with officers, representatives, and staffs of various agencies and groups were used as data sources when other sources were unavailable. The sources contacted include:

72. Commonwealth Development Corporation, Swaziland Irrigation Scheme.

73. Engineering and Power Development Consultants. Sitcup, England.

74. Ministry of Agriculture and Cooperatives.

75. Ministry of Finance and Economic Planning.

76. Ministry of Health.

77. Ministry of Industry, Mines and Tourism.

78. Ministry of Works, Power and Communications.

79. Swaziland Electricity Board.

80. Swaziland National Trust Commission.

81. UNEP/WHO/UNICEF Pilot Project.

82. USAID/Swaziland.

83. Water and Sewerage Board.

HYDROLOGY DATA SOURCES

The governments of Swaziland and the Republic of South Africa provided streamflow and reservoir abstraction records from several sources, which were consulted to develop hydrological data.

84. Commonwealth Development Corporation and other firms.

85. Government of Swaziland.

86. Government of Mozambique.

87. Government of the Republic of South Africa.

SECTION U

AUTHORITIES

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FACSIMILE HEADER SHEET
(ER 105-1-5)

FROM (Name)	OFFICE SYMBOL	TELEPHONE NO.	RELEASER'S SIGNATURE		ENG FORM 4460 1 FEB 73
Olyo Lansing	DAEN-TA	202 272-0006	Olyo Stanet		
TO (Name)	OFFICE SYMBOL	TELEPHONE NO.	# PAGES	PRECEDENCE	DTG
Mr Thomsen	MRD	402 221-7379	1	Priority	29 May 80

SUBJECT Complete Pkge is being mailed

MAY 30 9 59 AM '80

PASA
PARTICIPATING AGENCY SERVICE AGREEMENT
BETWEEN THE AGENCY FOR INTERNATIONAL DEVELOPMENT AND
Department of Defense
Corps of Engineers

(Mo., Day, Yr.) o/a June 15, 1980

2. PROJECTED COMPLETION DATE (Mo., Day, Yr.) September 30, 1980

3. CATEGORY [X] TDY [X] ASSIGNED

4. DURATION OF FUNDING [ ] CURRENT YEAR [ ] FORWARD FUNDING

5. PROJECT NO. AND TITLE 698-0135
Program Development and Support
Preliminary Water Resources Dev. Plan

[X] AMENDMENT 1

7. PASA NUMBER DS/SWAZ-0135-1-79

8. COUNTRY/AID/W OFFICE Swaziland

9. TYPE [ ] REIM. [X] GRANT [ ] LOAN

10. YEAR FY 19 80

11. FUNDING

A. CITATIONS	(1) APPROPRIATION NO. 72-1101021.6	(2) ALLOTMENT NO. 046-61-698-00-69-01		(3) PIO/T/OBLIGATION NO. 698-0135-2-6107340
B. AMOUNT	(1) INITIAL OR CURRENT $300,000	(2) CHANGE (+ OR -)		(3) NEW TOTAL $300,000
C. TOTAL PROJECT COSTS	(1) PRIOR YEARS (FOR CONTINUOUS PROJECTS)	(2) FUTURE YEARS (INCLUDE CURRENT FUNDING-BLOCKS B(1) OR B(3))		(3) ESTIMATED TOTAL
D. PRINCIPAL COST COMPONENTS (BLOCK B)	(1) SALARIES, DIFFERENTIAL AND BENEFITS $87,309	(2) TRANSPORTATION INCLUDING PER DIEM $51,910	(3) MISCELLANEOUS $122,100	(4) OVERHEAD $38,680
E. SUPPLEMENTAL AID SUPPORT	(1) INITIAL OR CURRENT	(2) CHANGE (+ OR -)		(3) NEW TOTAL

12. STATEMENT OF PURPOSE

I. Summary

This agreement between AID and the Corps of Engineers is to enlist their technical services in the preparation of a preliminary water and related land resources development plan to assist the Kingdom of Swaziland in meeting their need in the areas of agriculture, energy, and water supply (both municipal and industrial). Work under this PASA should commence at the earliest practical date in June and will take approximately 90 days to complete. Work will be coordinated closely with the Government of Swaziland (GOS), whose representatives will participate in the development of criteria for formulation and evaluation of alternative plans.

II. Duties and Responsibilities

General Study Approach

Full utilization will be made of existing data and prior studies. Limited field

13. GOVERNING PROVISIONS: PURSUANT TO THE GENERAL AGREEMENT DATED March 15, 1963 BETWEEN AID AND THE DOD, THE AGENCY NAMED ABOVE AGREES TO PROVIDE THE SERVICES OUTLINED IN BLOCK 12 AMPLIFIED AS NEEDED BY APPENDIX A UNLESS OTHERWISE AUTHORIZED BY AID. ALL SERVICES SHALL BE OF U.S. ORIGIN. ANY APPENDICES ATTACHED HERETO ARE CONSIDERED PART OF THIS PASA.

14. SIGNATURES

NAME: Marshall M. Haas
TITLE/OFFICE: Chief, Budget & Programs Division
Resource Management Office
Office, Chief of Engineers
DATE: 29 May 80

NAME: for H. L. Alexander J. William Auer
TITLE/OFFICE: CHIEF. PARTICIPATING AGENCY BRANCH CONTRACT MANAGEMENT. AID
DATE:

15. APPENDICES

[X] APPENDIX A - SCOPE OF WORK
[X] APPENDIX B - BUDGET PLAN
[ ] OTHER/REFERENCE

16. NEGOTIATING OFFICERS

AID: CM/SOD/IIA:ALJones A L Jones
AGENCY: DAEN-ZG:Col. EMMayson

COPY

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

REPLY TO
ATTENTION OF:
DAEN-IA

20 May 1980

SUBJECT: Technical Assistance to Swaziland

Division Engineer, Missouri River

1. The U.S. Army Engineer Division, Missouri River, is tasked to provide technical assistance to the Government of Swaziland (GOS). The immediate assistance required is to perform water resources development study and produce a plan for the GOS use in preparation for the forthcoming negotiations with the Republic of South Africa (RSA).

2. Last Fall, Ohio River Division (ORD) sent a team to Swaziland and a report "Review and Analysis of Water Resources Planning and Development in Swaziland" was produced. Your team should use the Terms of Reference and other data contained in the ORD report and place emphasis on the overall water resource needs of Swaziland and impact of water resource developments by the Republic of South Africa on commonly shared water resources between the GOS and RSA. The final product, if appropriate, should include a technical proposal for follow-on reimbursable work by the GOS.

3. Travel to Swaziland in conjunction with this mission assignment is contingent upon approval of increased travel ceiling for the Corps of Engineers. You will be advised accordingly when this is resolved. The Agency for International Development will provide funds for the study. Request a plan of action for the study, identification of team members with a biographical sketch on each, and estimated fund requirements with a breakdown of travel, per diem, and salary be provided to DAEN-IA as soon as possible.

4. The inclosed Letter of Instruction (inclosure 1) provides general guidance for conduct of studies and preparation of technical proposals for foreign governments.

/S/

1 Incl
as

JAMES A. JOHNSON
Major General, USA
Acting Chief of Engineers

C O P Y

WATER RESOURCES MANAGEMENT FRAMEWORK PLAN

FOR THE

KINGDOM OF SWAZILAND

TERMS OF REFERENCE

INTRODUCTION

1. The scope of work covered in this document includes studies and investigations necessary to develop a conceptual framework water and related land resources management plan for the Kingdom of Swaziland. The geographic area covered includes those portions of watersheds within Swaziland. Portions of international watersheds lying in the Republic of South Africa and Mozambique will be considered to the extent necessary to determine the availability of surface water and the implementability of potential plans.

2. The objective of this study is to develop a conceptual (outline) plan which will provide a framework for future development decisions concerning the nation's current and future water resources needs.

3. In accordance with national objectives as stated below, the water resources plan will seek to optimize the current national priorities, and objectives as follows:

Maximize employment opportunities;
Increase government revenue;
Increase value added;
Provide additional foreign exchange earnings;
Import substition; and
Protect and enhance the environment for the long-term benefits of the country.

4. For the purposes of water demand analysis, the near-term (1985), mid-term (2000), and ultimate needs will be determined.

5. The work to be accomplished pursuant to this terms of reference shall be performed prior to 31 August 1980, and shall entail development of a conceptual plan.

6. The study shall consider water resource needs for three alternative projections of population and land use. These alternatives shall reflect different assumptions regarding future land use patterns, economic developments, and population growth.

COPY

7. Two alternative assumptions shall also be made regarding the availability of surface water resources. One assumption will be based on the effects of existing projects in RSA. The other assumption will be based on full development of water resources projects in RSA.

8. Three sets of criteria shall be used in the formulation and evaluation of alternative plans:

(1) Financial (Internal Rate of Return)
(2) Economic (Internal Rate of Return)
(3) Overall Contributions to Swaziland's objectives outlined in paragraph 3.

9. Work efforts shall be coordinated closely with GOS, with representatives of GOS participating in development of criteria for use in making alternative population, land use, economic and border-flow projections.

STUDY MANAGEMENT AND COORDINATION

10. The team leader will coordinate study activities with the designated representative of the GOS. The designated representative will arrange for meetings with representatives of other government ministries.

GENERAL STUDY APPROACH

11. Full utilization shall be made of existing data and prior studies. Field investigations, reconnaissance surveys, and other basic data collection efforts shall be undertaken as a part of this contract only to the extent that they are considered necessary to develop the conceptual/framework plan.

12. Supplemental rainfall and hydrologic data, which are required to provide data on a monthly basis, shall be provided by GOS.

13. For base examinations required to determine future water needs, the Consultant shall subdivide Swaziland into study areas. These study areas shall approximate the lowveld, middleveld, and highveld portions of river basins under study. For each study area, alternative future water demands shall be estimated based upon the three alternative population, economic, land use, and other parameters for each area.

14. Based upon a comparison of demands and supplies alternative conceptual development plans will be formulated to eliminate (or minimize) inter- and intra-basin imbalances. These conceptual/framework plans shall be screened by the GOS in consultation with the study team. These plans shall be denoted as "tentative" plans and one or more of them shall be used by GOS formulate and establish a national posture and to negotiate with neighbouring countries.

BASE STUDIES

15. Population Analysis - The estimates of existing fertility mortality and migration for Swaziland shall be provided by GOS. Projections of fertility, mortality and migration, shall be made after analysis of existing data and discussions with GOS. Three population projections shall be made using combinations of alternative migration, fertility and mortality, which results in high, low, and "most-probable" conditions.

16. Economic Base Studies - The existing economic base, the economic development goals and objectives, preliminary population projections, land use capability data, and transportation profile will be reviewed.

17. Land Use Analysis - Analysis of land use shall be performed to determine existing uses and future use capabilities. Such analysis shall be performed for each of the individual study areas. Primary emphasis shall be given to agricultural uses. Soils and land capability maps for Swaziland and the existing soil survey report by Murdoch shall be provided by GOS.

18. Evaluation of Electricity Demands - Information regarding historical electricity demands and systems operational characteristics shall be provided to the Consultant by GOS. Electricity demand analyses previously performed for or by GOS also shall be provided and such studies shall be fully used as appropriate.

ANALYSIS OF WATER DEMANDS

19. Consumptive Uses - Total water demands shall be determined for each alternative projection scenerio. These estimates shall be arrived at by estimating the unique requirements of each major consumptive use category. The requirements of irrigated agriculture shall be given primary attention. Other uses will be considered according to the relative priority of each use identified as studies progress and the GOS development goals are quantified. In the analysis of water demands, consideration shall be given to the quality characteristic of such demands as appropriate.

20. In accordance with the long-term electric power demand projections, the forecasts of consumptive water requirements shall consider the potential future cooling-water need of steam electric power generation.

21. For irrigation requirements, the projections shall reflect seasonal characteristics of such demands.

ANALYSIS OF WATER SUPPLY

22. Surface Water - Using available data the existing and future surface water resources available within each study area shall be analyzed and

assessed. Determination of monthly low flow and high flow sequence intervals shall be made using frequency analysis. Future analyses of surface water availability shall consider as appropriate the anticipated changes in land use, including afforestation projections.

23. Groundwater - GOS shall provide all available information pertaining to the quantity and quality of groundwater. The Consultant shall analyze all information which has been compiled and estimate the extent of the groundwater resource, and the availability within each study area.

PROBLEM IDENTIFICATION

24. For each of the three socio-economic projections, the relationship between water demands and water supplies shall be compared for each study area. For each projection, the nature and extent of water quality and water supply problems shall be determined. The impact of the water deficiencies on the assumed socio-economic scenerio's shall be interpreted. Study areas where the availability of water poses development constraints, and where water is in surplus shall receive special attention.

DEVELOPMENT OF POTENTIAL PROBLEM SOLUTIONS

25. The Consultant shall review all available studies and data regarding potential water resource developments in Swaziland. An inventory of potential development sites shall be compiled, together with appropriate notations and characterization regarding such sites. As appropriate, the Consultant shall perform field reconnaissance studies to obtain supplemental data. All mapping and photographic coverage for such sites shall be provided to the Consultant by GOS.

26. The listing of alternative development sites shall be screened by the Consultant to identify those sites having the most favourable development potentials. The screening process shall be performed using appropriate engineering criteria and preliminary cost scales developed by the Consultant. Available geologic data shall be provided by GOS. Supplemental geologic field reconnaissance shall be conducted by the Consultant; new core-drilling efforts shall not be undertaken by the Consultant. Based upon all available information, the listing of sites shall be reduced to a small number of sites having potential for meeting future water resource needs. Potential projects shall be ranked according to their effectiveness in mitigating water resource problems.

27. Irrigation Potentials - The Consultant shall determine the irrigation potential for each site. These potentials shall be expressed in terms of acres of irrigation by individual study area, total acres of irrigation, irrigation benefit per unit for storage.

28. Hydroelectric Power Potentials - The Consultant shall determine the hydroelectric power potential for each site, GOS shall provide available projections of needs and plans for future power development.

29. For each site, the Consultant shall determine the generation output per unit of storage and the hydroelectric benefits per unit of storage.

PRELIMINARY PROJECT FORMULATION

30. Within the constraints of the accumulated demands in each study area and each river basin, the Consultant shall use "order of magnitude" cost and benefit data and perform marginal analysis necessary to formulate each project. The formulation process shall begin by considering the "sing-purpose project having the largest benefit per unit of storage. Project size will be increased by adding increments of storage (from highest to lowest valued purposes) until reasonable multi-purpose projects are determined. Each project shall be formulated separately.

PLAN FORMULATION AND EVALUATION

31. Plan formulation shall consist of an overall review of the effectiveness of different combinations of projects on the mitigation of water resources problems within the individual study areas. The Consultant shall recognize that individually formulated projects may not necessarily perform efficiently in combination with one another. The Consultant shall qualitatively evaluate the effectiveness of alternative plans and determine the probable impacts of making individual project adjustments. Since this task is simply "preliminary" plan formulation, and since the selection of preliminary plans are needed at a very early date, mathematical systems analysis shall not be performed. Alternative plans shall be presented to the GOS task force.

SPECIFICATION OF STUDY OUTPUTS

32. Studies shall be documented in the following reports:

(1) Supply-Demand Analysis - This document will outline the surface water supply situation based on the alternative population and land use analysis assuming full utilization of flows by RSA. A draft of this document will be completed by study team prior to departure from Swaziland;

(2) Summary Report and Annexes - This document would include the following information:

I Executive Summary
II Supply-Demand Analysis Annex
III Base Studies Annex

This document would be provided to GOS prior to 31st August 1980.

(3) Outline of Future Activities - This document would outline the detailed studies and activities necessary for the implementation of the specific plans or plan components contained in the Summary Report. It would provide a basis for future terms of reference for follow-on activities. This document would be provided by 30 September 1980.

PART V

PLATES

PART V

PLATES

LIST OF PLATES

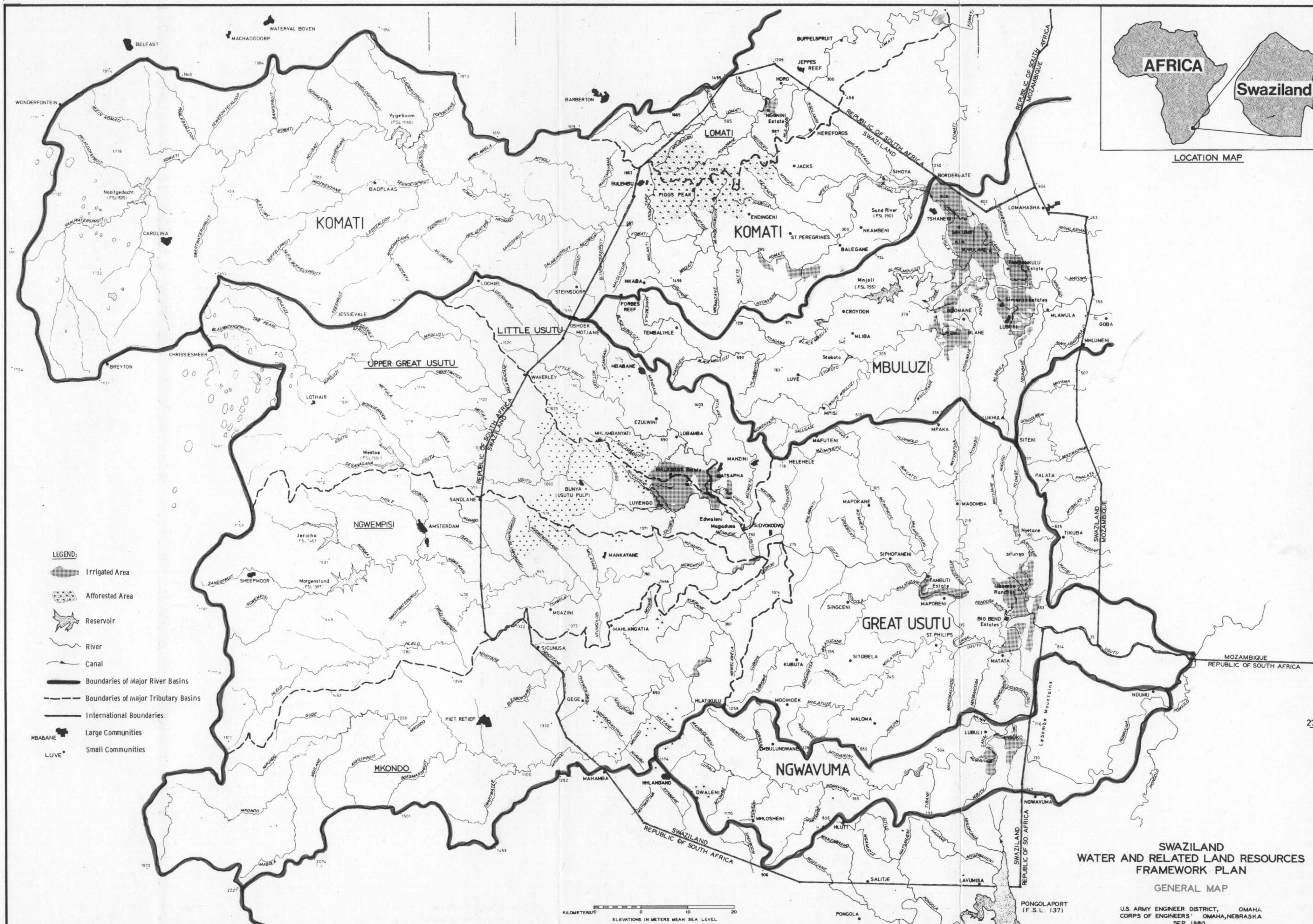

SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
GENERAL MAP
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS' OMAHA, NEBRASKA
SEP. 1980
LOCATION MAP
AFRICA
Swaziland
LEGEND:
Irrigated Area
Afforested Area
Reservoir
River
Canal
Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
MBABANE Large Communities
LUVE Small Communities
KILOMETERS 10 0 10 20
ELEVATIONS IN METERS MEAN SEA LEVEL
KOMATI
LOMATI
MBULUZI
LITTLE USUTU
UPPER GREAT USUTU
NGWEMPISI
GREAT USUTU
MKONDO
NGWAVUMA
REPUBLIC OF SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
BELFAST
MACHADODORP
WATERVAL BOVEN
WONDERFONTEIN
CAROLINA
BREYTON
CHRISSIESMEER
BADPLAAS
BARBERTON
PIGGS PEAK
BULEMBU
JACKS
ST. PEREGRINES
BALEGANE
NKAMBENI
TSHANENI
BORDERGATE
LOMAHASHA
CROYDON
MLIBA
MLAWULA
GOBA
MHLUMENI
LOCHIEL
STEYNSDORP
JESSIEVALE
OSHOEK
MOTJANE
MBABANE
WAVERLEY
EZULWINI
LOBAMBA
MANZINI
LUVE
MPISI
MAFUTENI
MPAKA
LUKHULA
SITEKI
PALATA
TIKUBA
LOTHAIR
AMSTERDAM
SANDLANE
SHEEPMOOR
PIET RETIEF
MANKAYANE
MGAZINI
MAHLANGATIA
SICUNUSA
GEGE
MAHAMBA
NHLANGANO
DWALENI
MHLOSHENI
HLATIKULU
MOOIHOEK
MBULUNGWANE
MALOMA
KUBUTA
SITOBELA
SIPHOFANENI
MAPOBENI
BIG BEND Estates
LUBULI
NDUMU
NGWAVUMA
LAVUMISA
SALITJE
PONGOLA
PONGOLAPORT (F.S.L. 137)
Lebombo Mountains
27°

PLATE I

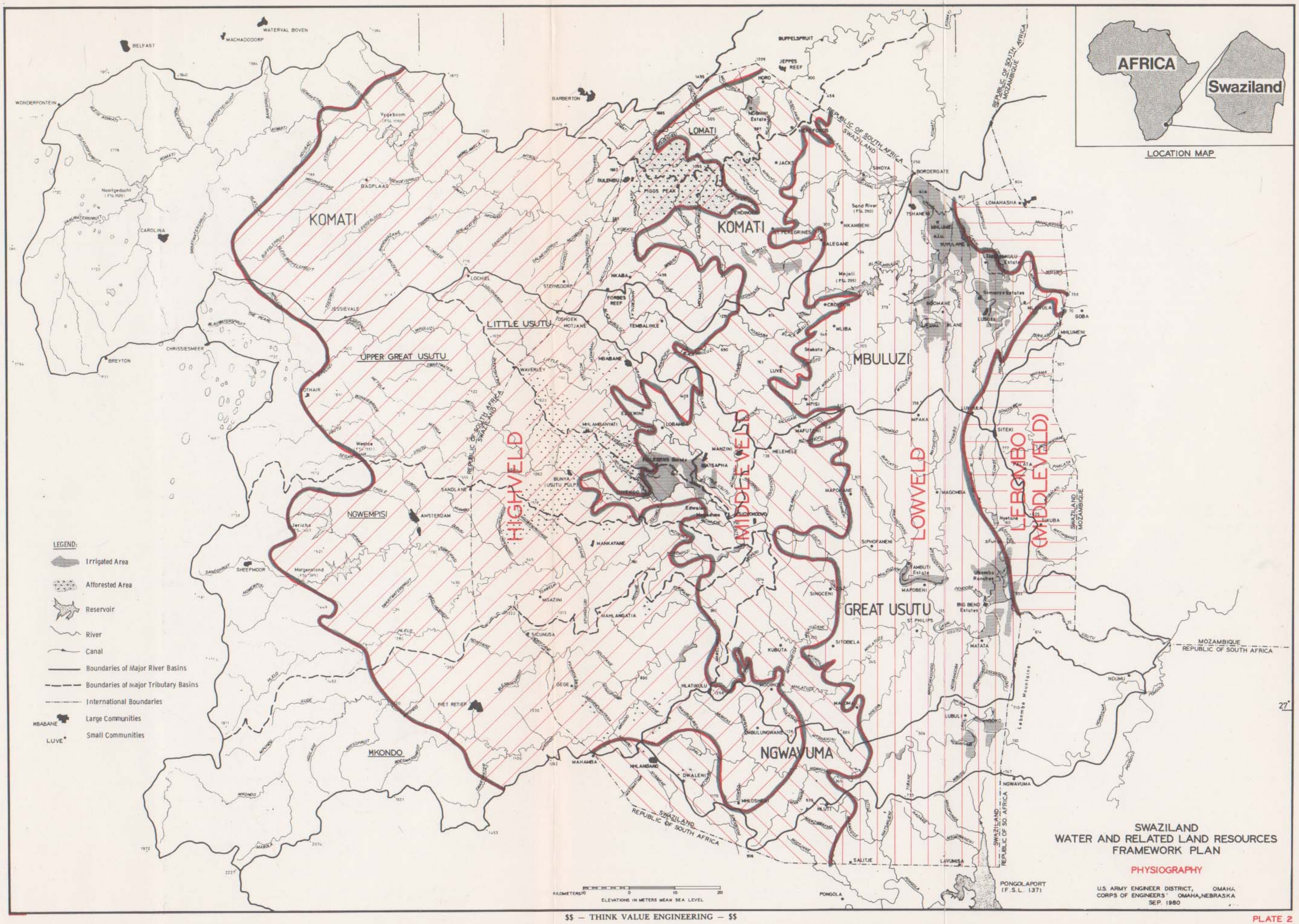
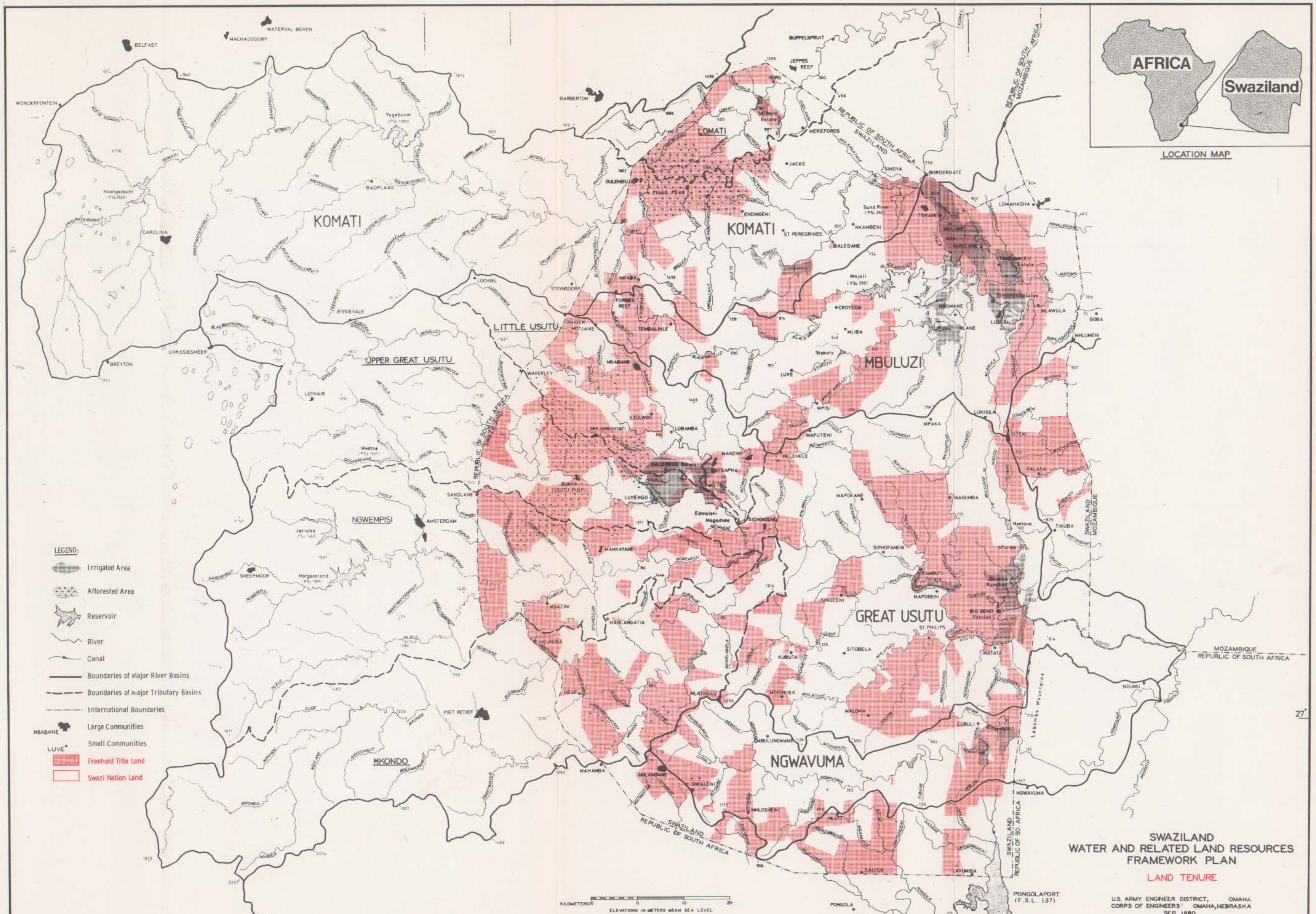


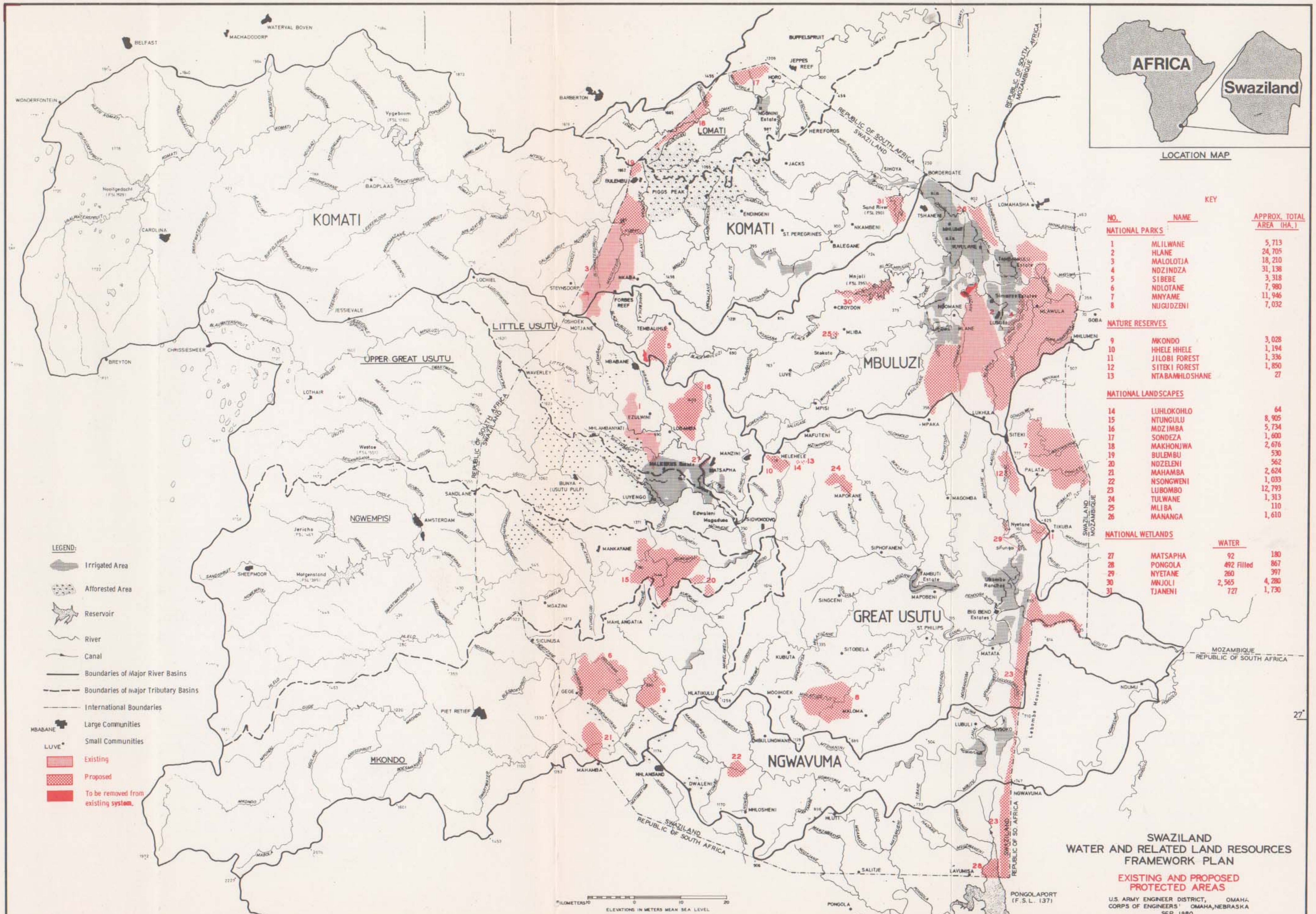
PLATE 2

U.S. GOVERNMENT PRINTING OFFICE



AFRICA
Swaziland
LOCATION MAP
KOMATI
LOMATI
LITTLE USUTU
UPPER GREAT USUTU
MBULUZI
NGWEMPISI
GREAT USUTU
NGWAVUMA
MKONDO
REPUBLIC OF SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
LEGEND:
Irrigated Area
Afforested Area
Reservoir
River
Canal
Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
Large Communities
Small Communities
Freehold Title Land
Swazi Nation Land
KILOMETERS 10 0 10 20
ELEVATIONS IN METERS MEAN SEA LEVEL
SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
LAND TENURE
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS' OMAHA, NEBRASKA
SEP. 1980

PLATE 3

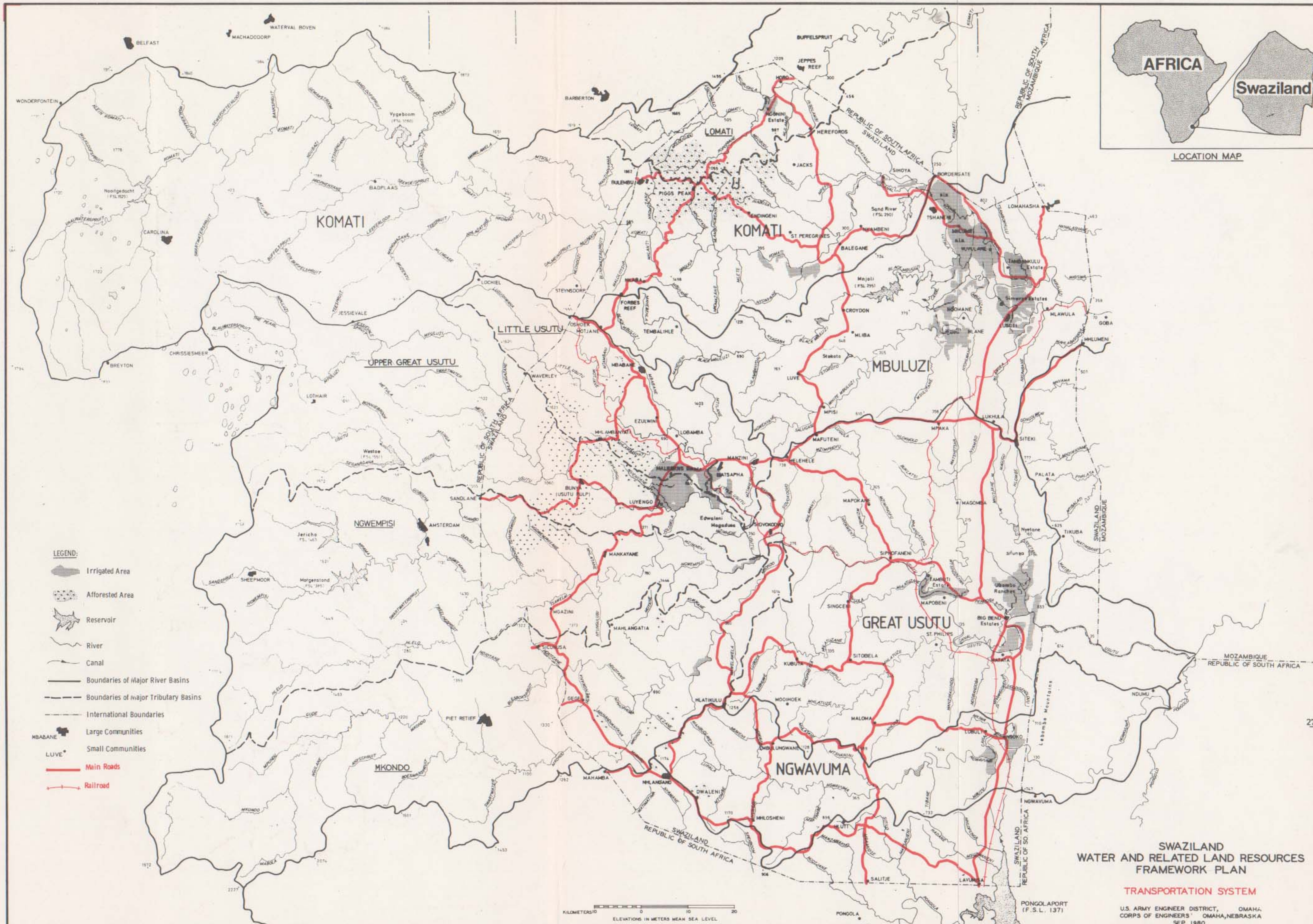


KEY

NO.	NAME	WATER	APPROX. TOTAL AREA (HA.)
NATIONAL PARKS			
1	MLILWANE		5,713
2	HLANE		24,705
3	MALOLOTJA		18,210
4	NDZINDZA		31,138
5	SIBEBE		3,318
6	NDLOTANE		7,980
7	MNYAME		11,946
8	NUGUDZENI		7,032
NATURE RESERVES			
9	MKONDO		3,028
10	HHELE HHELE		1,194
11	JILOBI FOREST		1,336
12	SITEKI FOREST		1,850
13	NTABAMHLOSHANE		27
NATIONAL LANDSCAPES			
14	LUHLOKOHLO		64
15	NTUNGULU		8,905
16	MDZIMBA		5,734
17	SONDEZA		1,600
18	MAKHONJWA		2,676
19	BULEMBU		530
20	NDZELENI		562
21	MAHAMBA		2,624
22	NSONGWENI		1,033
23	LUBOMBO		12,793
24	TULWANE		1,313
25	MLIBA		110
26	MANANGA		1,610
NATIONAL WETLANDS			
27	MATSAPHA	92	180
28	PONGOLA	492 Filled	867
29	NYETANE	260	397
30	MNJOLI	2,565	4,280
31	TJANENI	727	1,730

$$ — THINK VALUE ENGINEERING — $$

PLATE 4



SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
TRANSPORTATION SYSTEM
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS' OMAHA, NEBRASKA
SEP. 1980
LOCATION MAP
AFRICA
Swaziland
LEGEND:
Irrigated Area
Afforested Area
Reservoir
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Boundaries of Major River Basins
Boundaries of Major Tributary Basins
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BREYTON
LOTHAIR
AMSTERDAM
SHEEPMOOR
PIET RETIEF
BARBERTON
BUFFELSPRUIT
JEPPES REEF
HEREFORDS
PIGGS PEAK
BULEMBU
MBABANE
MANZINI
LOBAMBA
MATSAPHA
LUYENGO
MANKAYANE
SANDLANE
SICUNUSA
MHLANGATIA
HLATIKULU
NHLANGANO
MAHAMBA
DWALENI
MHLOSHENI
LAVUMISA
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PONGOLAPORT (F.S.L. 137)
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MAPOBENI
MALOMA
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NDUMU
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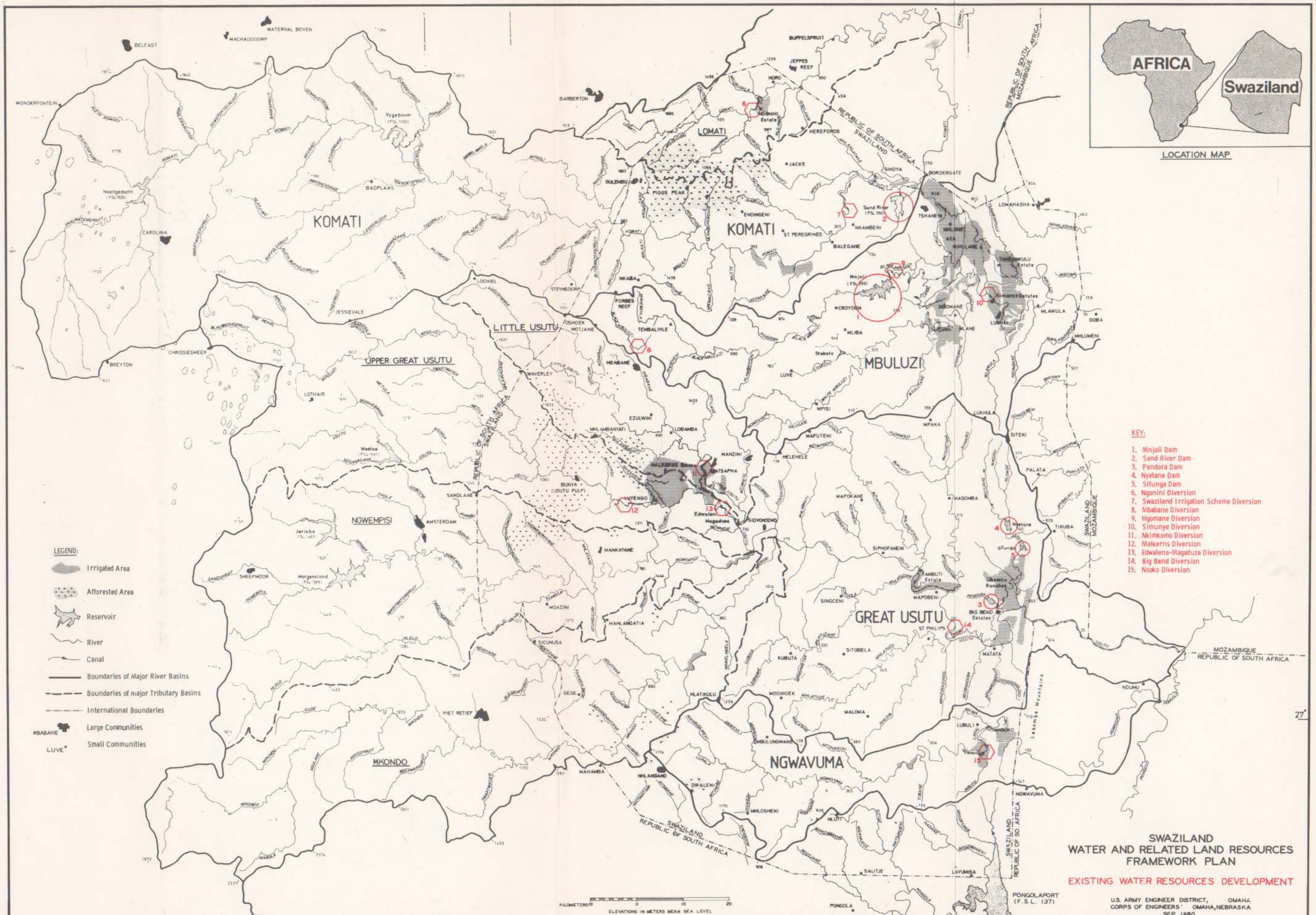
ELEVATIONS IN METERS MEAN SEA LEVEL



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Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
Large Communities
Small Communities
KEY:
1. Mnjoli Dam
2. Sand River Dam
3. Pendora Dam
4. Nyetane Dam
5. Sifunga Dam
6. Ngonini Diversion
7. Swaziland Irrigation Scheme Diversion
8. Mbabane Diversion
9. Hgomane Diversion
10. Simunye Diversion
11. Nkimkomo Diversion
12. Malkerns Diversion
13. Edwalena-Magaduza Diversion
14. Big Bend Diversion
15. Nsoko Diversion
KILOMETERS 10 0 10 20
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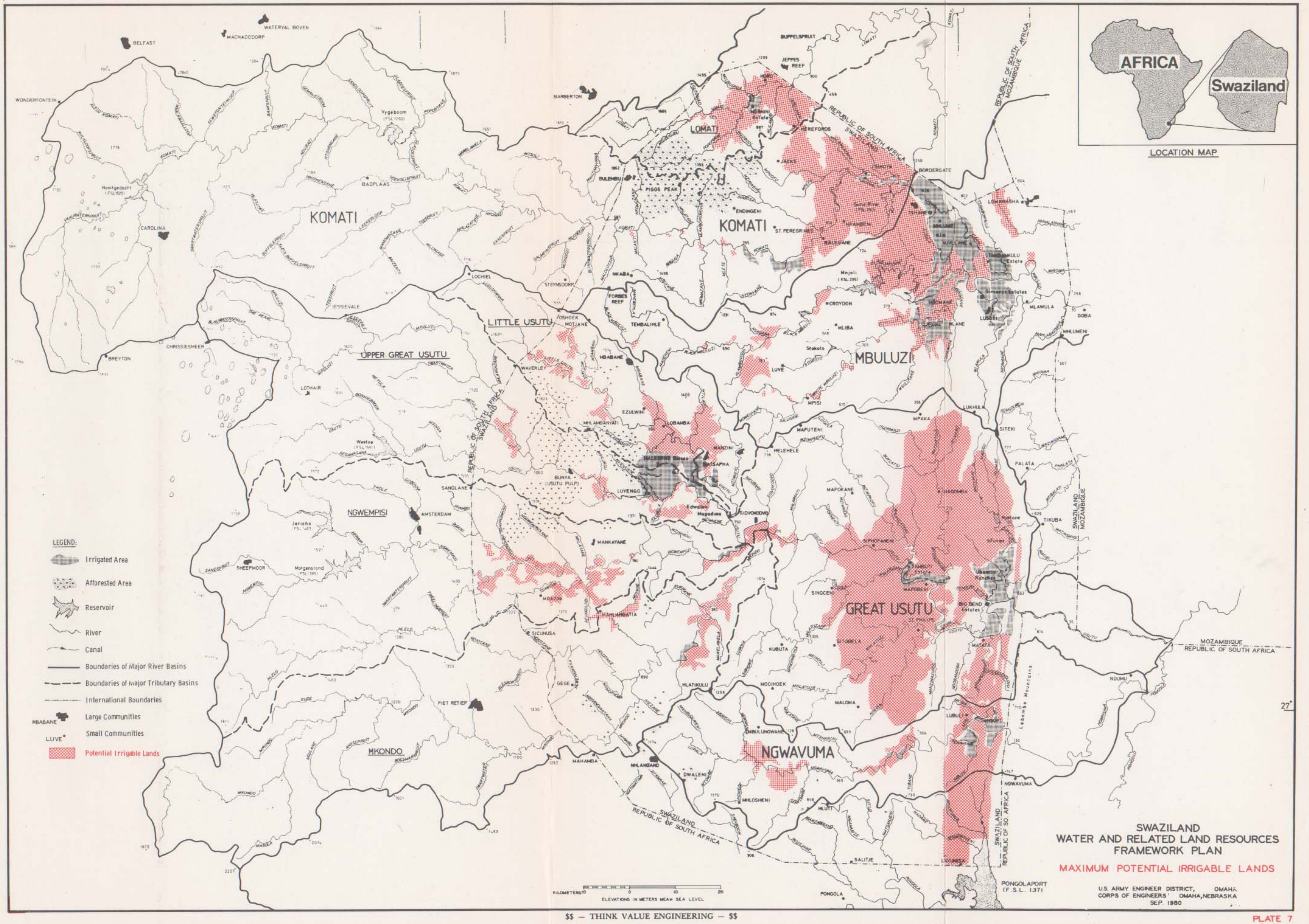
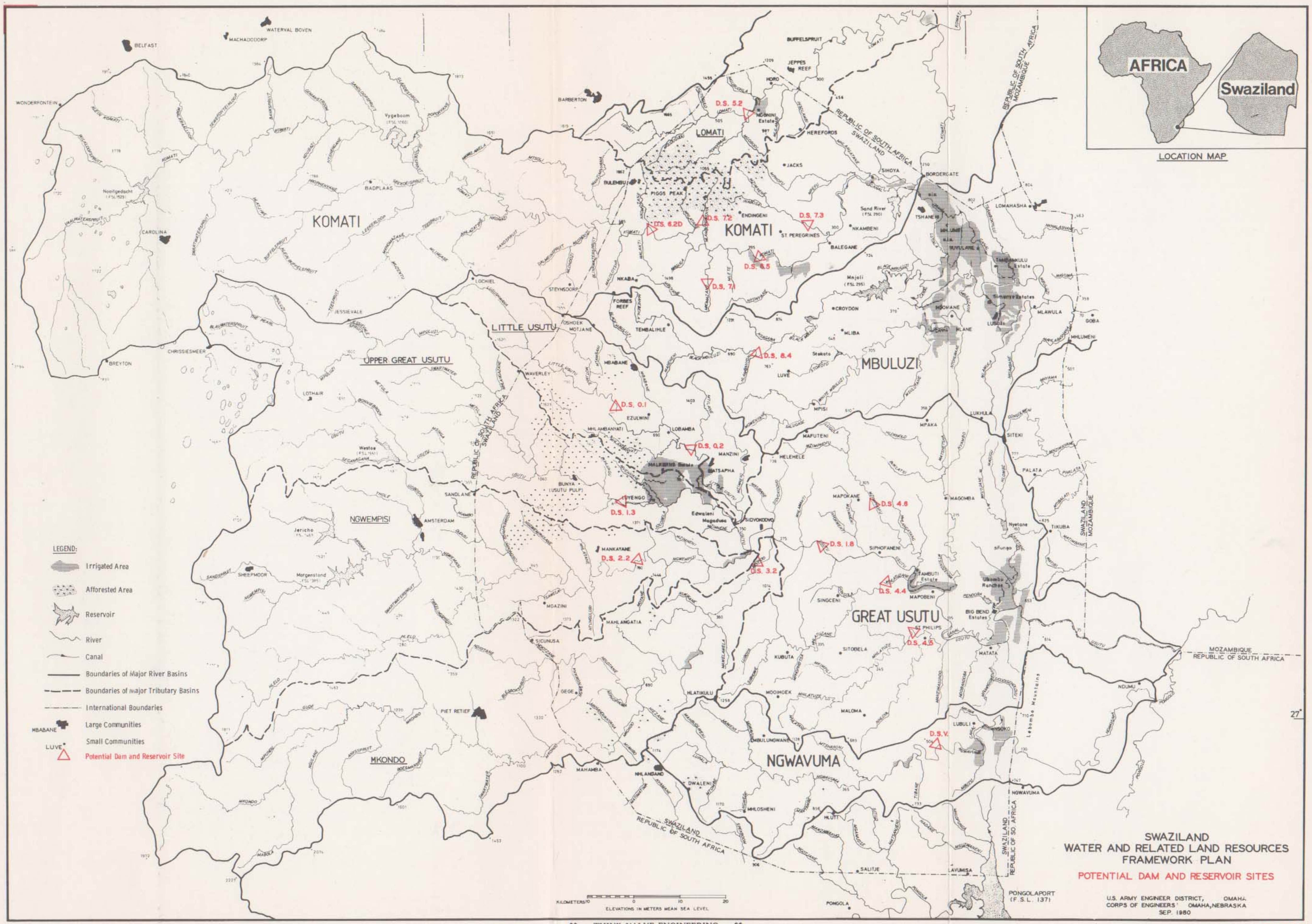
FRAMEWORK PLAN
EXISTING WATER RESOURCES DEVELOPMENT
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980

PLATE 6



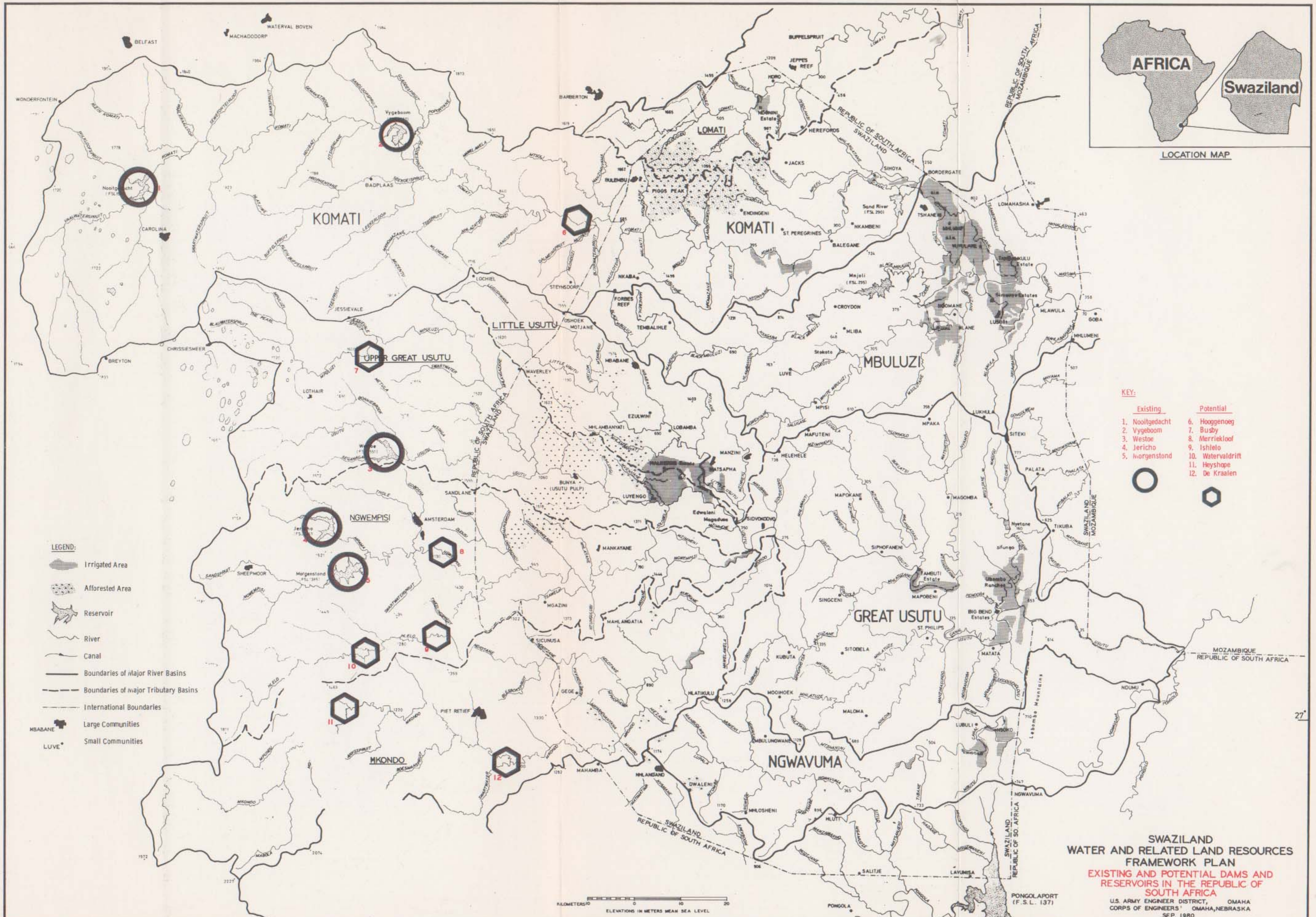
AFRICA
Swaziland
LOCATION MAP
KOMATI
LITTLE USUTU
UPPER GREAT USUTU
NGWEMPISI
MBULUZI
GREAT USUTU
NGWAVUMA
MKONDO
REPUBLIC OF SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
LEGEND:
Irrigated Area
Afforested Area
Reservoir
River
Canal
Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
Large Communities
Small Communities
Potential Irrigable Lands
MBABANE
LUVE
KILOMETERS
ELEVATIONS IN METERS MEAN SEA LEVEL
SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
MAXIMUM POTENTIAL IRRIGABLE LANDS
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980

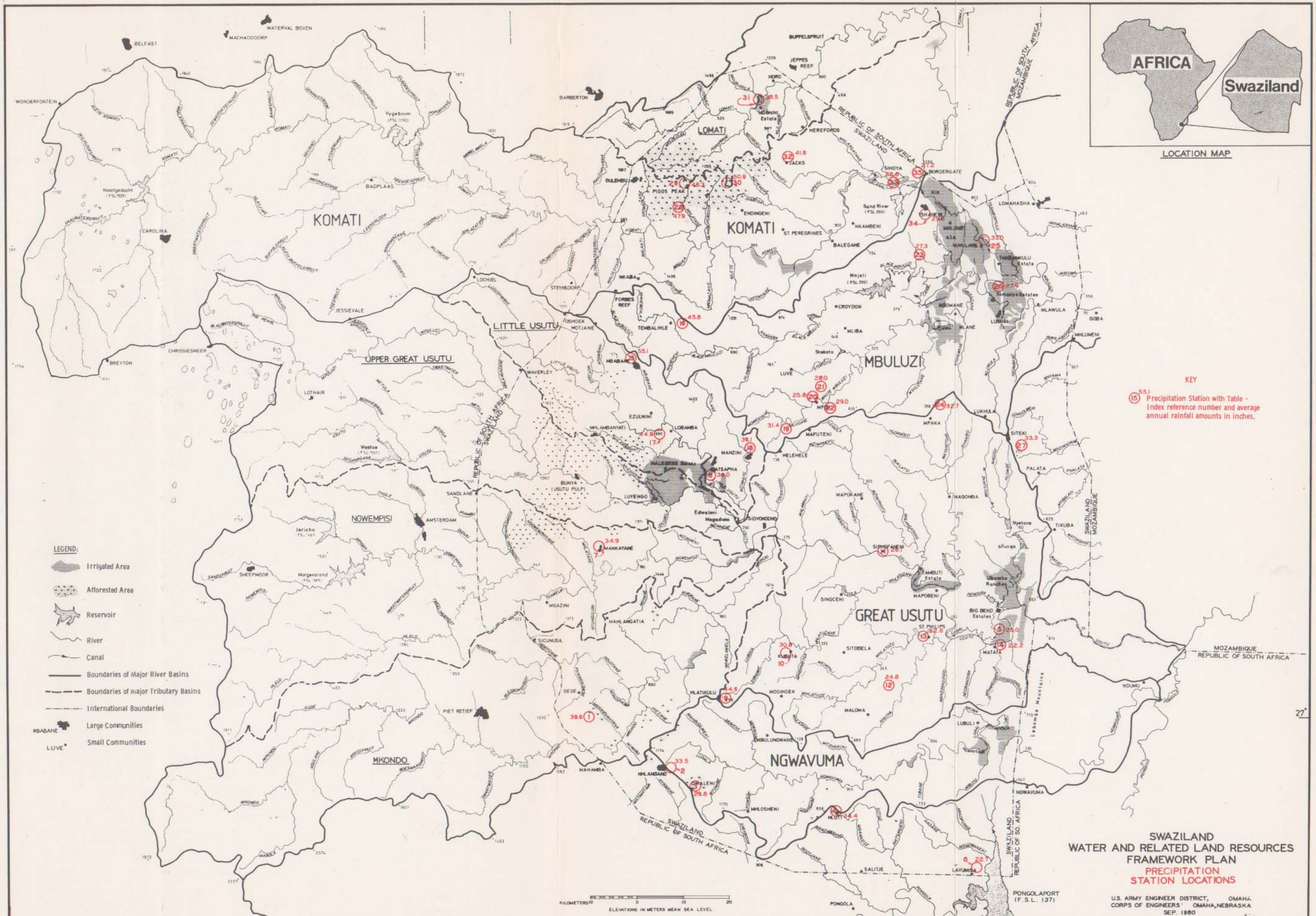
PLATE 7



SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
POTENTIAL DAM AND RESERVOIR SITES

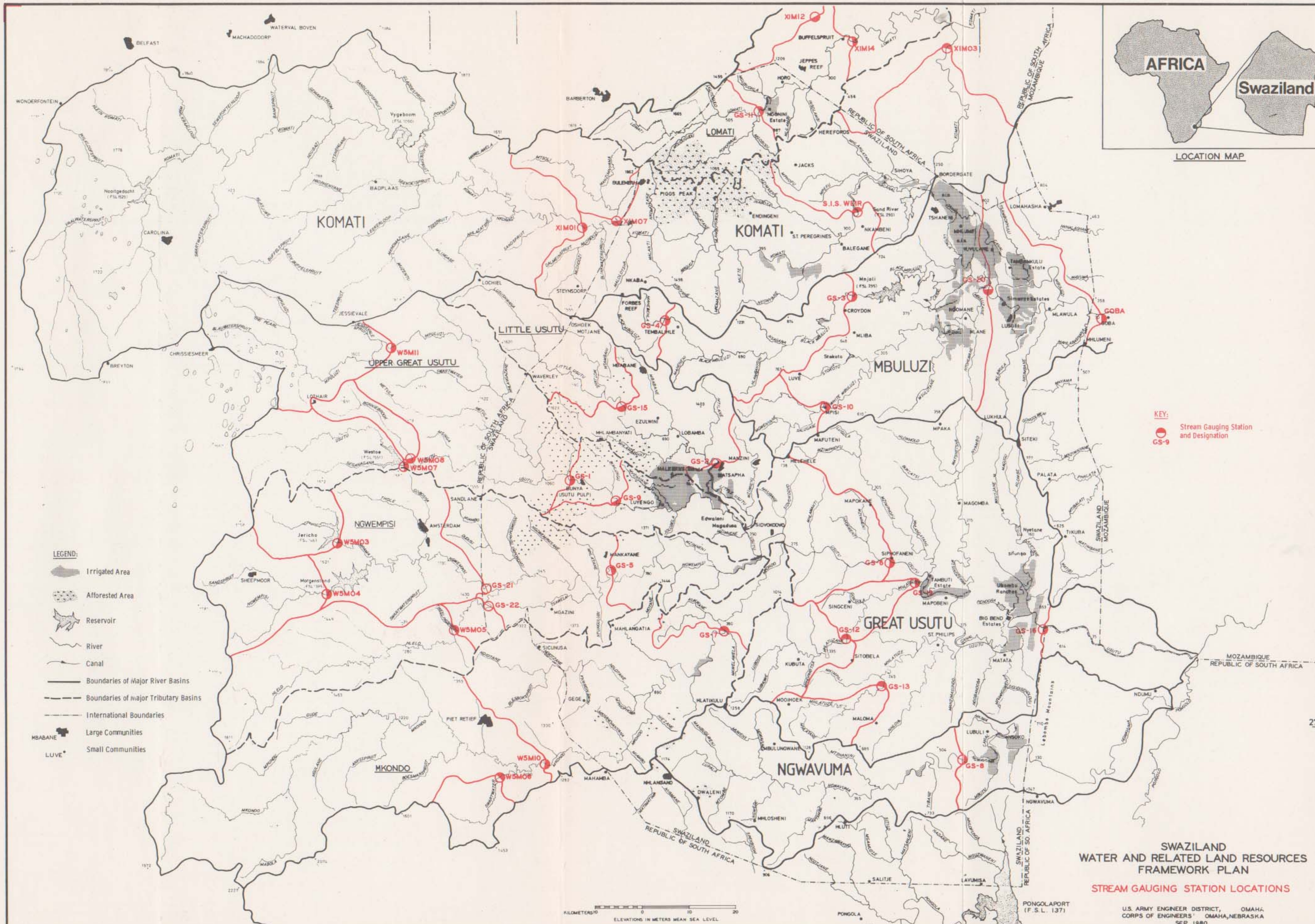
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS' OMAHA, NEBRASKA
SEP. 1980

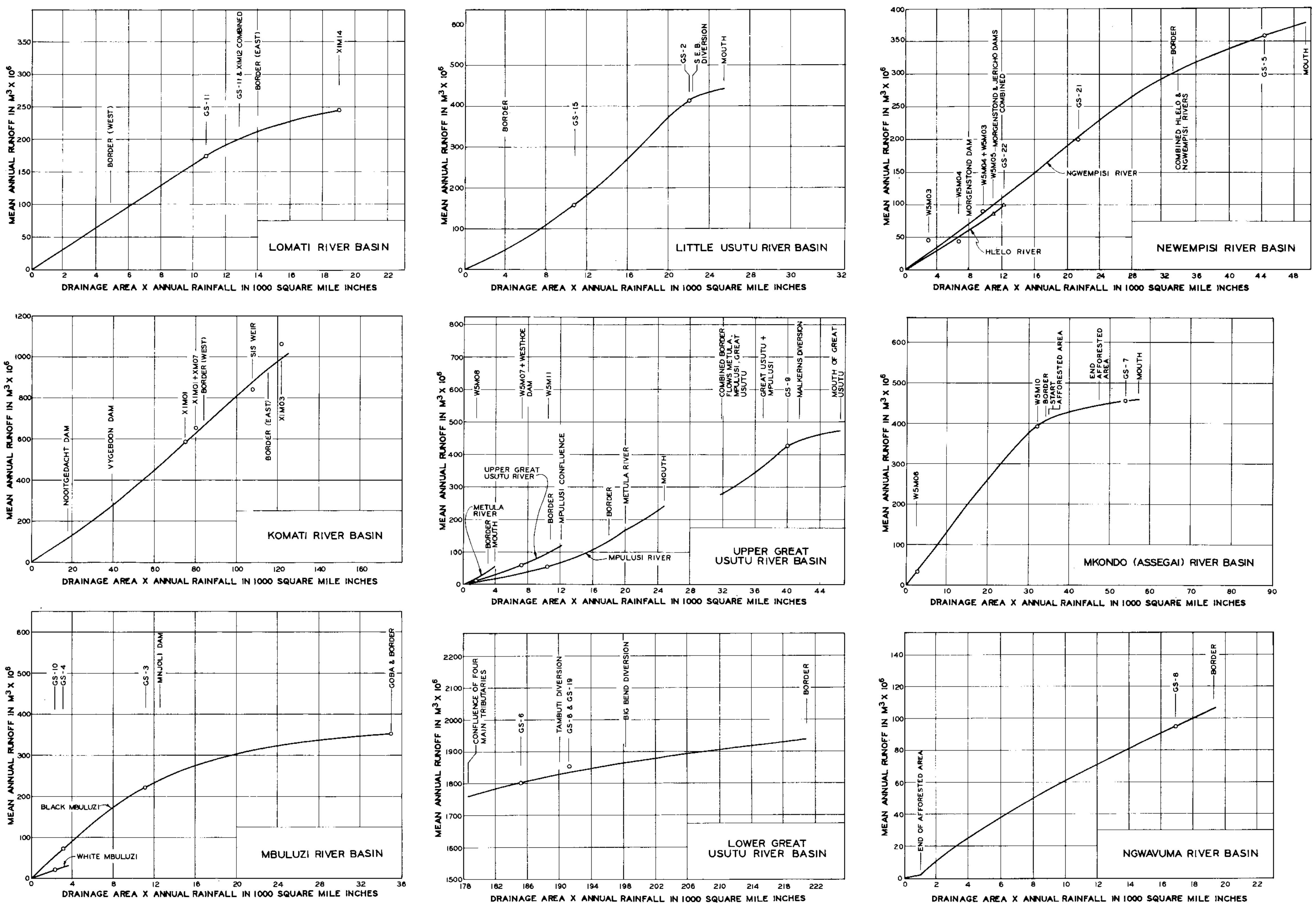

SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
EXISTING AND POTENTIAL DAMS AND
RESERVOIRS IN THE REPUBLIC OF
SOUTH AFRICA
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS' OMAHA, NEBRASKA
SEP. 1980
LOCATION MAP
AFRICA
Swaziland
KEY:
Existing
1. Nooitgedacht
2. Vygeboom
3. Westoe
4. Jericho
5. Morgenstond
Potential
6. Hooggenoeg
7. Busby
8. Merriekloof
9. Ishlelo
10. Watervaldrift
11. Heyshope
12. De Kraalen
LEGEND:
Irrigated Area
Afforested Area
Reservoir
River
Canal
Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
Large Communities
Small Communities
MBABANE
LUVE
KOMATI
LOMATI
LITTLE USUTU
UPPER GREAT USUTU
MBULUZI
NGWEMPISI
GREAT USUTU
MKONDO
NGWAVUMA
REPUBLIC OF SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
BELFAST
MACHADODORP
WATERVAL BOVEN
WONDERFONTEIN
CAROLINA
BADPLAAS
BARBERTON
BREYTON
CHRISSIESMEER
LOTHAIR
AMSTERDAM
SHEEPMOOR
PIET RETIEF
PIGGS PEAK
MANZINI
SITEKI
LOMAHASHA
PONGOLAPORT
(F.S.L. 137)
KILOMETERS
ELEVATIONS IN METERS MEAN SEA LEVEL



$$ — THINK VALUE ENGINEERING — $$

PLATE 10


SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
STREAM GAUGING STATION LOCATIONS
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980
LOCATION MAP
AFRICA
Swaziland
KEY:
Stream Gauging Station and Designation
GS-9
LEGEND:
Irrigated Area
Afforested Area
Reservoir
River
Canal
Boundaries of Major River Basins
Boundaries of Major Tributary Basins
International Boundaries
MBABANE Large Communities
LUVE Small Communities
KOMATI
LOMATI
LITTLE USUTU
UPPER GREAT USUTU
MBULUZI
NGWEMPISI
GREAT USUTU
NGWAVUMA
MKONDO
REPUBLIC OF SOUTH AFRICA
SWAZILAND
MOZAMBIQUE
KILOMETERS 10 0 10 20
ELEVATIONS IN METERS MEAN SEA LEVEL



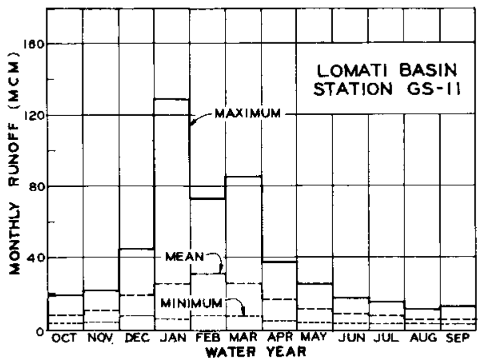
NOTE: Values computed at gauging stations are based on flow records adjusted to reflect conditions without any man-made water developments.

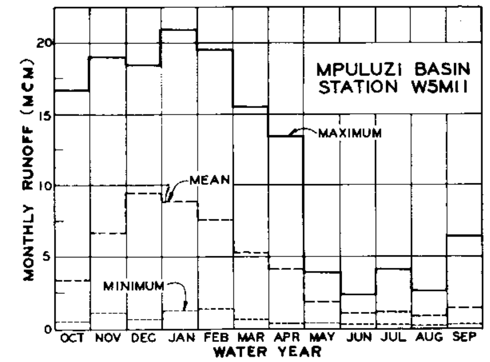
Annual rainfall is average for the period of record.

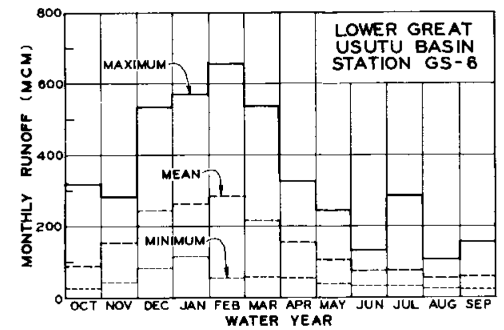
THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

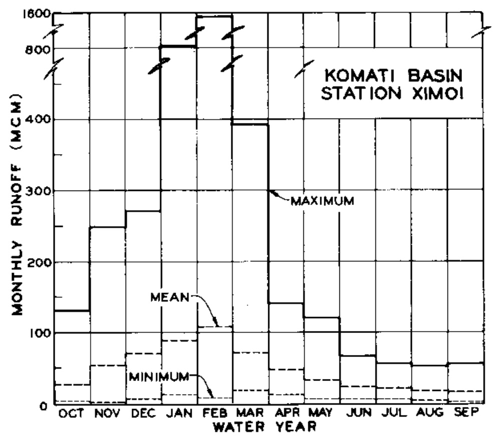
SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
SEMI NATURAL
MEAN ANNUAL RUNOFF

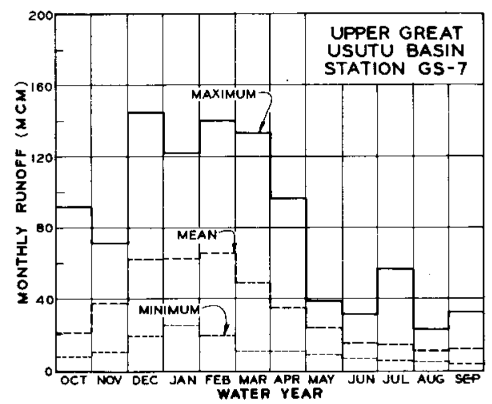
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980

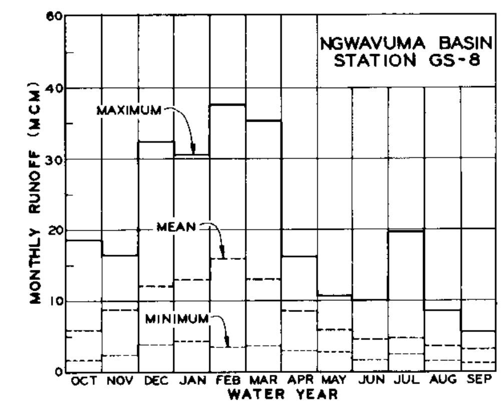


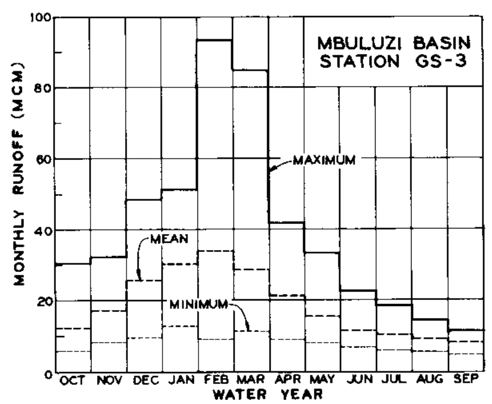


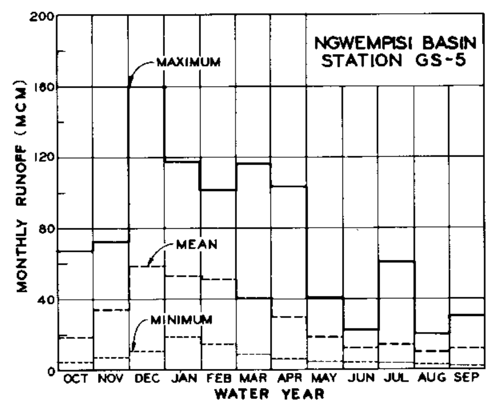




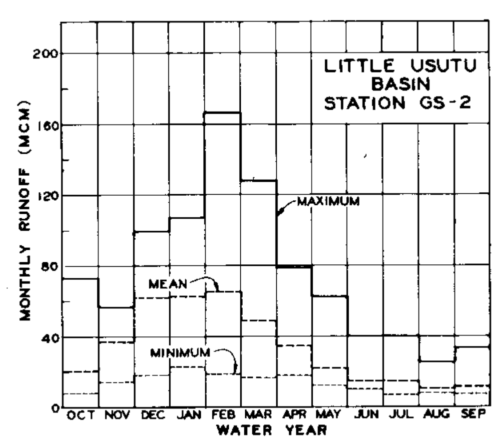


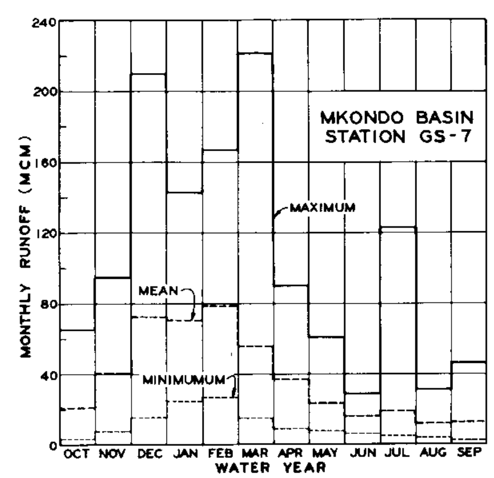






NOTE: Flows are recorded flows adjusted for the effects of man-made water developments.

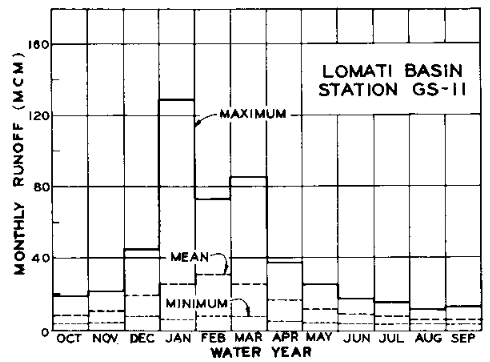


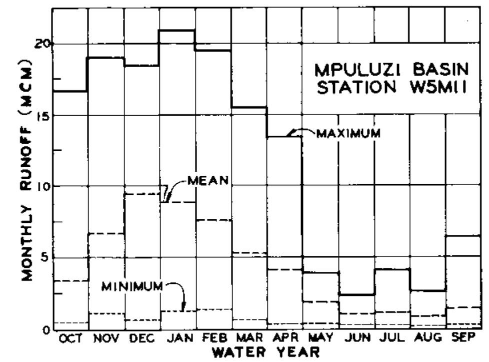


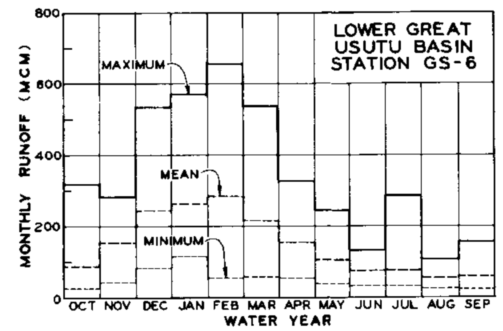
SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
MAXIMUM MINIMUM & MEAN MONTHLY
FLOWS AT SELECTED STREAM
GAUGING STATIONS

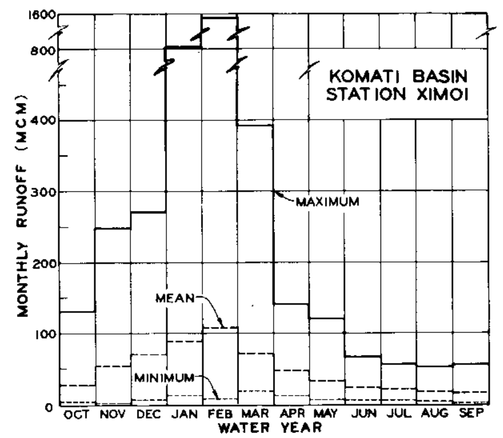
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980

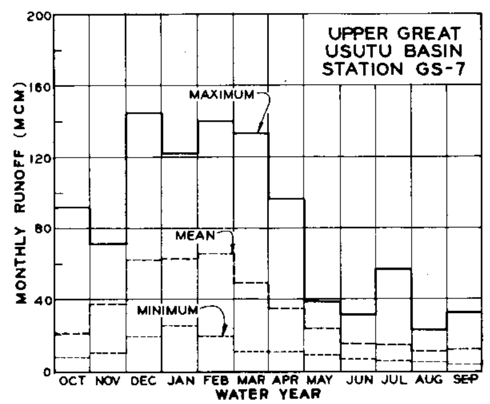
$$ – THINK VALUE ENGINEERING – $$

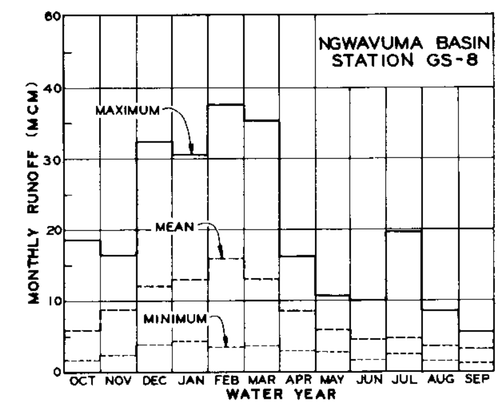


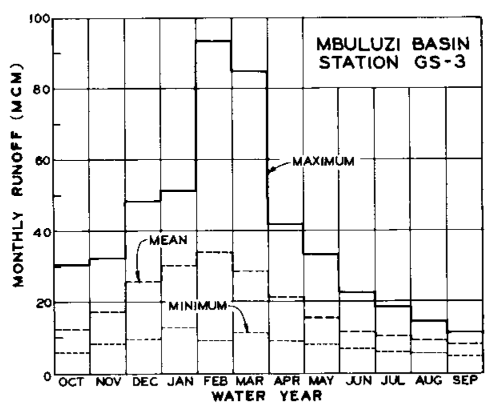


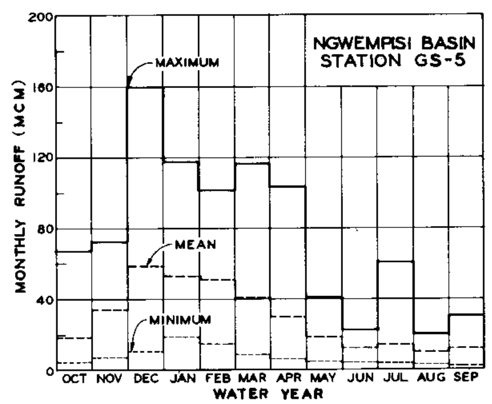




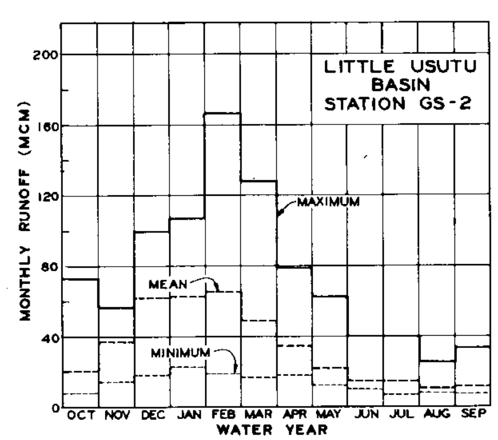


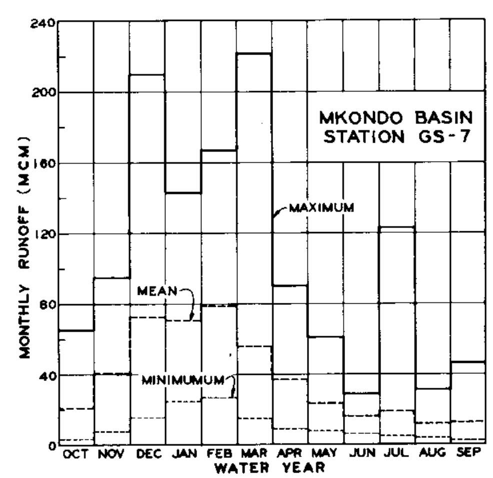






NOTE: Flows are recorded flows adjusted for the effects of man-made water developments.





SWAZILAND
WATER AND RELATED LAND RESOURCES
FRAMEWORK PLAN
MAXIMUM MINIMUM & MEAN MONTHLY
FLOWS AT SELECTED STREAM
GAUGING STATIONS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA
SEP. 1980

PLATE 13